FIRE REGIMES CLASSIFICATION FOR CONIFEROUS FORESTS OF THE NORTHWESTERN UNITED STATES

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Fire Regimes Classification for Coniferous Forests of the Northwestern United States

Final Report

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Introduction

Researchers and managers have identified a need for a fire regimes classification system for use in forest management (Sando 1978, Heinselman 1978, 1981; Kilgore 1981). Previous publications (Heinselman 1981, 1985; Kilgore 1981, 1987) have described theoretical fire regimes classifications but have not used statistical techniques to analyze site-specific fire history data. Numerous studies describe fire history in the Western United States, however, suggesting that such a classification methodology is possible.

Extrapolation of fire history characteristics to similar site types across a broader area may be useful if there has been sufficient redundancy among the findings from detailed studies. Generally, managers and researchers have found natural resource classification systems to be useful for many management concerns. For example, managers have found guides such as Davis et al.'s (1980) 'Habitat Type Fire Groups' to be a valuable fire ecology reference source. But such guides have limitations. First, the guides usually have a relatively limited scope, that is, there have been few attempts to organize and group ecologically similar habitat- and forest cover types into a broader "fire regimes" classification. Second, classifications often cover relatively limited geographical areas, such as a particular national forest. Accordingly, the following study was undertaken to develop a fire regimes classification that would utilize the substantial body of fire history data that exists for coniferous forests throughout the Pacific Northwest.

Objectives

The overall objective of the study was to develop a fire regimes classification that describes fire frequencies, severities, spread patterns, and fire sizes based on vegetational, topographic, and climatic variables. Specific objectives were to

1. Review fire history studies for the Northwestern United States and adjacent Canadian provinces, and summarize each study area's topographic, vegetation, fire history, and climatic variables.

2. Analyze relationships between the fire history variables and the topographic, climatic, and vegetation variables.

3. Develop a classification system of fire regime types based on the statistical analysis.

4. Compile a report which summarizes the data base, the data analysis, and the resultant fire regimes classification.

Methods

Literature Review. The first phase of the study was to review and compile data from fire history studies, including both published and unpublished reports, for the geographic region encompassing Montana, Idaho, Oregon, Washington, northwestern Wyoming, southern Alberta, and southern British Columbia. Quantitative fire ecology studies and forest succession studies which focused on fire ecology were examined as potential sources of information on fire history (methods for interpreting fire history data from these studies are discussed below).

The following criteria were used in judging a given study's usefulness. Before the review process, it had been anticipated that a relatively liberal acceptance policy would be necessary to obtain as large a data base as possible. In practice this meant that a substantial amount of data interpretation would be required because there is no standard fire history research methodology or research reporting format. To be useful, the reports had to provide relatively detailed descriptions of study area topography, vegetation, and fire history or fire ecology.

If a report failed to provide every one of the desired descriptors (listed

below), it was not immediately rejected as a potential source of information. First, other data sources were consulted that might possibly list information for that study area (e.g., vegetation classification studies). Second, it was anticipated that substantial interpretation of the data within most reports would be necessary in order to prepare a consistent data base for statistical analysis. Specific interpretation techniques that evolved during the review process are discussed below, or later in this report under "Literature Review Results."

The 2 most critical categories, however, were the vegetation and fire history variables since data on a study area's topography and climate usually can be obtained elsewhere (described below). Descriptions of the vegetation were sought for the stand level of analysis, and the most-useful reports would include information on stand cover type and habitat type (potential climax vegetation). The stand cover types would then be classed according to Eyre's (1980) S.A.F. cover type classification. Habitat types would be determined, if not listed in the report, by referring to any area vegetation classification studies.

Next, detailed information was sought for fire history statistics that applied to each of the study area's forest types: 1) fire frequencies at the stand level (mean fire intervals, range of individual fire intervals), 2) fire effects (severities), and 3) fire burning patterns (spread uniformity and fire sizes). Ideally, these data also would be stratified according to both the pre- and post Fire Suppression eras, but information on the Fire Suppression era was not absolutely necessary because the primary goal was to develop a fire regimes classification for natural ecosystems. (Most fire history reports provide this information, however).

The studies' variables were listed on a data sheet that was designed to ensure a consistent data base (Appendix A). The variables were grouped

according to 4 categories: 1) topography, 2) vegetation, 3) fire history, and 4) climate. Following is a list of the desired variables and their assigned classes (codes are the lower-case letters or numbers):

A. Topographic variables:

1. Study area surface form. This was determined by referring to the geographic landform system shown in Appendix B:

   a. Smooth plain.

   b. Irregular plain.

   c. Rough plain.

   d. Plateau (tableland).

   e. Hills with narrow valleys.

   f. Open hills (hills with broad valleys).

   g. Mountains with narrow valleys.

   h. Mountains with broad valleys.

   i. Plateau-like mountains.

   j. Plains with mountains (Basin-and-Range topography).

2. Overall degree of stand dissection. If not indicated in the study, an estimate of the stand's dissection class was made by examining 7.5 minute- or 15 minute topographic maps of the area, then subjectively determining a dissection class by comparing the area's erosion patterns to a template (Appendix C). (There is no widely used system for economically determining land dissection [pers. comm. with Glacier National Park Geographer C. Key]). The 3 classes defined in this study were:

   a. Highly dissected.

   b. Moderately dissected.

   c. Lightly dissected.

3. Elevation range for stands within each habitat type. If not indicated in the study, elevation range was estimated from topographic maps.

4. Slope range for stands within each habitat type. If not indicated in the report, slope was estimated from the topographic maps by using the rise/run formula listed in Rothermel (1983):

a. flat to 10 percent

b. 10-40 percent

c. 40-75 percent

d. 75+ percent

5. Aspect for stands within each habitat type. If not indicated in the report, aspects were determined from topographic maps. Three classes were defined:

a. northerly

b. southerly

c. flat

B. Vegetation variables: (listed for both the pre- and post Fire Suppression era, if possible).

1. Size in acres of smallest sample unit (e.g. grove, stand). The "small stand" level of analysis was desired (no specific stand-size definition), since the fire history variables would always be calculated for that level, if possible.

2. Forest cover type for each sample stand, stratified according to Eyre's (1980) S.A.F. classification.

3. Forest habitat types by series and association for each sample stand, if described. If not described in the report, habitat types were determined to at least the series level by referring to appropriate area classifications or by extrapolating from nearby studies which discussed climax vegetation. The habitat type association was identified to at least the potential climax life form (e.g., grasses, low shrubs, tall shrubs) in all cases. The

association's life form class was considered acceptible for the statistical analysis (defined and explained later in this report).

4. Stand physical structure and ages of stand age classes. The following 2-code system was used to characterize the stand's overstory and understory (e.g., "c/d"). This information was interpreted from stand descriptions if the desired format (below) was not detailed precisely in the report. If estimation was not possible, the report was rejected as a potential data source.

a. Immature overstory.

b. Mature overstory.

c. Over-mature overstory.

m. Highly mixed

d. Dense tree understory.

e. No dense tree understory.

5. Stand age class structure, and list the number of classes. This information was interpreted from stand descriptions if the desired format (below) was not detailed precisely in the report. If interpretation was not possible, the report was rejected as a potential data source.

a. even-aged.

b. uneven-aged.

C. Fire history variables: The following variables were sought, for each habitat type (stand), for the pre- Fire Suppression and Fire Suppression era. If not listed, the variables were interpreted from stand descriptions:

1. Source of fire history evidence (enter all appropriate codes):

a. Fire scars.

(1) Single- or double-scarred trees.

(2). Multiple-scarred trees.

b. Post-fire even-aged regeneration.

c. Fire scars and post-fire regeneration.

d. List the number of years of the fire history record.

e. List beginning year of fire suppression period (Note: if not indicated in the report, extrapolate the year from nearby studies, if possible).

2. Fire frequency variables per habitat type (stand), rounded to nearest whole-year value. If the desired frequency statistics (below) were not listed in the report, it was necessary to calculate the values by first developing stand master fire chronologies; this was done, if possible, by determining stand fire years (e.g., from fire maps), then subsequently calculating the descriptive statistics below. If it was not possible to estimate fire frequencies the report usually was rejected as a potential data source unless it contained other important fire data, for instance, on fire severities, that could supplement other studies of that vegetation type.

a. Minimum year-length of fire intervals.

b. Maximum year-length of fire intervals.

c. Mean fire interval.

d. Percent interval change during the Fire Suppression era (calculated, if possible, if not indicated in report). If it was not possible to estimate fire interval changes during the Suppression Period, no data were entered for the category. The calculation method was to divide the Suppression Period's minimum and maximum interval values by those for the pre-Suppression period. For example, if a stand's pre-Suppression fire intervals ranged from 5 to 10 years, and

the Suppression interval currently is 50 years, then 50/5 and 50/10 equals a 500 percent to 1000 percent increase in interval length during the Suppression Period. The following coding system was used to express the suggested percent-change value:

0 = intervals still within the pre-suppression range.

10 = intervals exceed natural range by 10 percent.

20 = intervals exceed natural range by 20 percent.

(etc...)

3. Fire severity within the stand. If fire severities were not discussed in the report the information was interpreted, if possible, by examining stand structure information (e.g., stand species composition and age class structure, presence and type of fire scars). If it was not possible to estimate fire severities, the report usually was rejected as a potential data source. Three severity classes were defined:

a. Primarily non-lethal surface fires.

b. Primarily stand-replacing fires.

c. Mixed pattern.

4. Fire sizes in the study area: The following fire size classes were defined. If fire sizes were not discussed in the report, no data were entered for the fire size category (reports were never rejected for failing to provide this information because the fire history literature frequently does not present fire size data).

0. less than 200 acres

a. 200 to 1000 acres.

b. 1000 to 5000 acres.

c. 5000 to 10,000 acres.

d. 10,000 to 50,000 acres.

e. 50,000+ acres.

5. Fire spread in the stand. If fire spread patterns were not discussed in the report the information was interpreted, if possible, by interpreting stand structure information (e.g., stand species composition and age class structure, presence and nature of fire scars). If it was not possible to estimate fire spread patterns, the report usually was rejected as a potential data source. Three classes were defined:

a. Uniform.

b. Non-uniform (i.e., primarily disjunct patches in the stand).

c. Mixed pattern (i.e., primarily uniform spread but with disjunct patches in the stand). Note: the "mixed pattern" class is somewhat similar to the "non-uniform" spread class, but the goal was to obtain a relatively detailed stratification of fire spreads.

D. Climatic variables: If not presented in the study, climatic data were derived by the following methods (if estimation was not possible, the report was rejected as a potential data source). First, long-term precipitation data (Pacific Northwest River Basin Commission 1969) and wind data (U.S. Weather Bureau 1959) were sought from weather stations that exist within an approximately 50-mile radius of the study area. The relatively liberal 50-mile value was considered necessary because study areas occasionally are remote from weather station sites, yet the topography and vegetation can be relatively similar. Otherwise, extrapolation was necessary (described below). The following data classes were defined:

1. Precipitation (nearest one-tenth inch):

a. Mean annual (preferably "Normal" value).

b. Mean for the fire season (July/August).

The following method was used to estimate the precipitation data when more-reliable data were not available. The estimation methods were used in 2

different situations: 1) to extrapolate precipitation data if no weather station existed within the 50-mile radius, and 2) to more accurately reflect likely precipitation increases with increasing elevation within a large study area (weather stations usually record values for lower elevations only).

First, data were extrapolated from the '<u>Columbia Basin Handbook</u>'s' (Pacific Northwest River Basin Commission 1969) isohyetal maps which portray precipitation means on small-scale maps of each state (1930-1957 period; scale: 1 inch/45 miles). (Although not specifically stated on the maps, the isoheyetal lines generally depict precipitation relative to increasing elevation). This method has potentially serious limitations however. First, the study area must be pinpointed on a small-scale map that shows limited geographical detail. Second, only approximate estimates of precipitation can be obtained from the maps, since adjacent isoheyetal lines have been rounded to increments ranging from 5 inches (xeric areas) to 20 inches (very moist areas) apart. Whenever possible, the extrapolations were checked for general agreement with any relatively nearby studies that provided detailed precipitation data for the forest types in question. Extrapolation without cross-referencing to nearby studies was used only as a last resort, but this situation was expected to be uncommon (i.e., there usually are weather stations or data from studies within a relatively short distance of a given study).

Means for fire season precipitation were obtained in a similar fashion, that is, by consulting records from nearby stations or by extrapolation. When extrapolation was necessary, the fire season mean was estimated by calculating the percent of annual precipitation that typically occurs in the study area during the July/August period--this was derived by examining the isohyetal maps, then examining the immediate region's station records an calculating what percent of annual precipitation was typical. (Examinations of groups of stations sugg[illegible] that they usually receive a closely similar July/August

percentage of the annual precipitation value). Following is an example of how extrapolation was used to adjust the precipitation values for Arno (1976) study area's lower-elevation forests: the valley-bottom weather station at Stevensville, Montana, recorded "normals" for mean annual precipitation of 12.71 inches and 1.62 inches for July/August (13 percent of the annual value). However, the isohyetal map for the area (Pacific Northwest River Basin Commission 1969) suggested that the lower forested slopes probably receive an annual average of about 15 inches and, hence, about 1.95 inches (13 percent) for the fire season.

2. Wind Data. Wind data were sought from Climatography of the U.S. (U.S. Weather Bureau 1959) which lists data for primary stations only. (This limitation could pose serious problems in terms of the data's validity: primary weather stations are located only at a few widely dispersed, valley-bottom airports, and an extrapolation method could not be devised). The following wind data were sought:

   a. Direction (cardinal compass points).

      (1). Regional.

      (2). Local.

   b. Velocity (mph).

      (1). Mean annual.

      (2). Calculate a mean for the fire season.

Statistical Methods. After the literature review was completed, the data were encoded and entered into a computer data base (program: dBase III Plus). The data base was organized in the following manner. The literature review data sheets for each study were reviewed and one or more "stand's" worth of data (i.e., samples) was entered for each habitat type in the report. Specifically, since most reports would be expected to produce a range of values for a given variable class, for example for slope steepness, multiple stands' worth of

information would result for that habitat type. As an example, if a report indicated that habitat type "X" was sampled on 3 different slope classes on one aspect, then data were entered for 3 "sample stands" in that habitat type. If habitat type "Y" occurred on 2 aspects and within 2 slope classes on those 2 aspects, then data were entered for 4 stands, and so on.

Statistical analysis was next conducted using the following methods (program: SPSS/PC+ [Statistical Package for the Social Sciences]). The data were first stratified according to dependent and independent variables. The fire history data are the dependent variables: 1) mean fire interval (MFI), 2) fire size class, 3) fire severity class, and 4) fire spread pattern. These dependent variables were further stratified according to the pre-suppression and suppression era categories.

The following data classes were the potential independent variables: 1) habitat type, 2) SAF cover type, 3) stand physical structure, 4) stand age class structure, 5) fire history evidence (e.g., fire scars, post-fire regeneration), 6) land surface form, 7) elevation class, 8) slope class, 9) dissection class, 10) precipitation class, and 11) wind speed and direction class.

Descriptive statistics. Descriptive statistics were first generated for each variable for all data samples, including: 1) sample point distribution by variable class, and 2) median and first four moments of each fire regime variable.

Descriptive statistics were then generated for each dependent (fire history) variable by each independent variable, specifically: 1) sample point distribution by fire history variable class for each independent variable class, and 2) mean, median, and standard deviation of each fire history variable for each independent variable class subpopulation.

Comparative Statistics/Classification. The following statistical methods were used to develop the fire regimes classification. The first step was to determine each independent variable's contribution to the variance of the dependent (fire history) variables. This was done by using one-way Analysis of Variance (ANOVA) on classified variables, and regression analysis on continuous variables. The goal was to identify any statistically significant independent variable classes.

The next step was to explore any potentially significant combinations of the independent variables by conducting multiple ANOVAs. The goal was to identify which groups of independent variables would be the most-significant predictors of a given "fire regime" (defined under "Results and Discussion). We felt that the potentially most fruitful approach would be to conduct an *a priori* analysis utilizing (Barrett's) ecological knowledge about the various vegetation and fire history variables. The plan was to guide the analysis at each level of exploration by what were felt to be logical, ecologically-based groups of potentially significant variables (specific avenues of exploration are detailed under "Results and Discussion"). An alternate but more time-consuming approach is cluster analysis, which assumes that the researcher has no prior knowledge about the variables being examined. Cluster analysis would be used in this study only if the *a priori* approach failed to produce a useful classification.

Results and Discussion

Literature Review. The literature review produced data from 52 studies, including both published and unpublished reports (Appendix D). The literature ranged from marginally- to highly detailed. For example, the reports often did not use the same research techniques and terminology for describing fire history and vegetation. The lack of standard research methods and terminology therefore necessitated varying degrees of data interpretation (previously

described) in order to derive the desired classes of variables. In general, studies conducted before about 1977 (27% of the 52 reports) required the most data interpretation because few detailed fire history methodologies existed before that time. Bob Marshall's (1928) study of the "life history" of several stands near the Priest River Experiment Station, Idaho, represents the earliest study in the literature review, but few studies preceeded 1970 (only 5 of 52 studies, or 10%).

As might be expected, I found that the studies which used Arno and Sneck's (1977), or similar, methods usually were easily understandable in terms of collecting data for the desired variable classes. Most of these studies occurred in the Northern Rockies and 20 were either conducted by Barrett or by S. Arno, or, had directly involved these authors in an advisory capacity; the 20 reports represent 65 percent of the 31 reports for that region, and 39 percent of all reports in the literature review. In contrast, studies conducted in the Cascade and Olympic Ranges occasionally seemed ambiguous in their methods and terminology, and consequently required the most interpretation on my part. This seems attributable to at least 4 factors: 1) few studies used the Arno and Sneck (1977) or similar methods, the ones most familiar to me, 2) 9 of the studies for that region were conducted before 1978 (1951 was the earliest), and consequently occurred before the development of relatively standard methodologies, 3) even if the "standard" methodologies are used, fire history can be difficult to document in coastal forests because of the often very long fire intervals, and 4) fire patterns in that region's highly diverse forests can be substantially more complex than in the Northern Rockies.

A few studies in the literature review do not appear, at face value, to be legitimate fire history reference sources (Appendix D). An example is Marshall's (1928) "Life history of some western white pine stands on the

Kaniksu National Forest" (northern Idaho). This was not a fire history study per se but it provided highly detailed descriptions of post-fire succession within several potential redcedar/western hemlock stands and it also listed the years between successive fires in the stands. Consequently, I was easily able to obtain detailed information for the fire regimes data base.

Agee and Smith's (1984) study of subalpine meadow succession on burned sites in Washington's Olympic Mountains also was not a fire history study. However, the study documented tree succession after 3 relatively recent fires on different sites (the fires occurred from 3 to 88 years before the sampling), and it allowed insight into the fire intensities, spread patterns, and patterns of post-fire regeneration in high altitude subalpine fir/mountain hemlock stands. The study thus helped build the otherwise limited data base for that forest type. In fact, I had to more frequently depend upon general fire ecology literature for that region because there have been fewer detailed fire history studies than in the Northern Rockies.

Quality of the Data Base. Following is a discussion of the apparent quality of the data that were gathered for each variable class in the literature review, in terms of their potential for statistical analysis.

Relatively high quality data were obtained for the studies' topographic variables. Descriptions of study area surface form and stand dissection usually were derived directly from the reports, or were easily interpreted from topographic maps. Most reports also provide information on elevation ranges for each forest type. However, reports usually provide only general descriptions of slope steepness, rather than specific slope percents. If any of the above topographic information was not presented in a report, however, it was easily interpreted from topographic maps at the University of Montana Mansfield Library.

Relatively high quality data ultimately were obtained for stand cover types

and habitat types at the series level, but the reports' descriptions of study area vegetation occasionally required a substantial amount of interpretation. For example, Marshall (1928) called his stands the "White Pine Type", but it was clear from his stand descriptions that the 3 stands would be classified today as redcedar/hemlock habitat types and white pine, larch, and redcedar/hemlock SAF cover types, respectively.

Habitat type associations often were not discussed in the reports. In some cases the association could be established by examining species information for understory grasses or shrubs, or by extrapolating from nearby studies which had described the potential vegetation in detail. As discussed later in this report, however, we felt that it would not be absolutely necessary to identify the habitat type association to the species level (relatively broad habitat type classes were established for the fire regimes classification).

The data on stand physical structures generally is of high quality. Overstory and understory tree structures usually were described in detail in the reports, as were maximum tree ages. Similarly, data on stand age class structures are a relatively standard aspect of fire history and fire ecology reports, or, such information usually can be interpreted by examining stand descriptions in conjunction with the data on fire history patterns.

Fire history data often were less straightforward than the data on topography and vegetation. Relatively high quality information ultimately was obtained, but often only after a substantial amount of interpretation of the reports' methods, terminology, and data. For example, some reports described "fire cycle" for a broad area rather than occurrence for small stands (e.g., MFI). In such cases, it was sometimes possible to derive the desired fire history variables for the stand level by examining descriptions of tree regeneration patterns and species composition, the patterns of fire scarring, and fire chronologies and fire locations based on stand mosaic maps.

Conversely, a given report usually was rejected as a potential data source if such information was not provided, thus making it impossible to re-construct stand fire history. Whenever such interpretation was conducted it was noted on the data sheet and the data were checked for general agreement with any studies that contained high quality fire history information for the same forest types.

In terms of data for the Fire Suppression period, reports were not rejected if they did not discuss post-1900 fire occurrence. (The goal was to develop a fire regimes classification based on presettlement fire history). Still, most studies provided this information and the resulting data on changes in fire frequency, fire patterns, and stand structures seem to be of high quality.

Many studies did not provide quantitative information on fire sizes. However, this was not grounds for rejection because relatively accurate estimates of past fire sizes can usually only be obtained from studies which examine forest mosaics (i.e., for even-aged stands which experienced stand-replacing fires). Fire sizes also can occasionally be obtained from modern-day fire atlases but, again, this information probably only accurately reflects typical presettlement fire patterns for those forests which historically experienced large stand-replacing fires (i.e., the atlas reflects escaped fires that burned in a largely natural pattern). Otherwise, the data base for fire sizes is incomplete and, is usually highly speculative on either the authors' or my part. Examinination of the data frequency distributions (described below) indicates that fire size data were not entered for 25 percent of the samples. Still, fire size information might be useful in describing fire history for the long-interval/stand-replacing fire types.

The data on fire spread patterns (i.e., uniform, patchy, mixed pattern) seems to be of high quality. Most fire history reports discuss this aspect, or, the information usually is easily interpreted by examining data on tree species, age class patterns, and tree fire scar patterns.

The climatic data vary in quality. For example, precipitation data (mean annual and mean fire season) usually were presented only in master's theses or dissertations. Much of the remaining data could be extrapolated from topographically similar weather stations. In the few cases when "blind" extrapolation was necessary, however, there was substantial potential for accuracy errors; adjacent isohyetal lines on the maps range from 5 to 20 inches apart (increments increase with progression to the very moist coastal areas). Still, the extrapolation methods descibed earlier seemed to be relatively accurate when compared with actual data from weather stations near similar forest types. The mean fire season values probably are more accurate because the dry summer months experience much less precipitation variation in the Northwest. That is, the weather records show that even very different forest types often receive relatively similar precipitation during the droughty summers. Estimation accuracy for the seasonal value probably is usually within .5 inches. To account for these potential errors, however, the fire regimes classification was not based on mean annual or seasonal precipitation, but on broad vegetation classes that indirectly reflect precipitation differences (discussed later in this report).

The wind data proved to be highly unreliable. Data on wind speeds and directions generally are only available for a few primary stations, that is, at airports located in major intermountain valleys. Examinations suggested that the wind values did not represent those within the adjacent mountain topography (the locations of most studies). For example, mean wind directions for the Missoula County Airport suggested that the recorded values were primarily influenced by the Missoula valley's topography; both the annual and fire season wind directions (13 yr. record) were northwest, yet the area's summer storms generally pass over the region from southwest to northeast. (The Missoula Valley drains to the northwest). Apparently non-representative

results also were suggested for the Boise (Idaho) Airport station (19 yr. mean July/August wind direction: northwest) and the Lewiston (Idaho) Airport station (9 yr. record: east and west/northwest). Broad-valley fetch undoubtedly exerts a strong influence on these local wind directions and also might be expected to produce wind speeds in excess of those in the adjacent dissected mountain topography. Consequently, the wind data were excluded from the analysis.

Frequency Distributions. The 52 studies produced data for 387 "stands" (samples) for the Presuppression Period (this number would double, to 774 samples, if the 387 stands were examined for both the Presuppression and Suppression Periods). Following is a summary of the frequency distributions for the 387 samples for the Presuppression Period, stratified by the major categories of variables. Note that the following percentage values do not necessarily indicate the "most studied" or "least studied" vegetation types. Some habitat- and cover types occur within a relatively wide range of slope steepnesses and aspects, thus more samples would have been entered for the types that have relatively wide ecological amplitudes (data base development previously described under "Statistical Methods"). For example, "Interior Douglas-fir" habitat types, which occur across a broad range of topography, account for 18 percent of all samples in that category, while the less widespread "ponderosa pine" habitat types account for only 5 percent. Both types, however, have been extensively studied.

1. Regional Distribution. In terms of the data's geographic distribution, 65 percent of the samples were from the northern Rockies and 29 percent were from the Cascades, for a total of 94 percent. The remaining data were from the Olympic Mountains (4%) and Blue Mountains (2%). The breakdown by state and Canadian province was: Montana (27%), Washington (18%), Idaho (17%), Oregon (15%), Alberta [illegible], Wyoming (3%), California (1%), and British Columbia (1%).

2. <u>Topography</u>. Of the 6 documented classes for study area surface form, 92 percent of the samples occurred in 2 classes: "mountains with narrow valleys" (65%) and "mountains with broad valleys" (27%). Four percent occurred in "open hills", 2 percent occurred on "plateau-like topography", 1 percent occurred in "rough plains", and .5 percent occurred in "hills with narrow valleys."

Of the 3 possible study area dissection classes, 76 percent of the stands were moderately dissected and the remaining 24 percent were lightly dissected. No stands were considered to be primarily highly dissected, perhaps refecting the fact that most fire history studies occur in the lower-elevation forests (highly dissected stands would occur most frequently in the high elevations, or, in breaklands topography).

Of the 4 slope classes, 85 percent of the samples occurred within 2 slope classes: the 10-40 percent slope class (44%) and the 40-75 percent slope class (41%). Thirteen percent were in the "flat-to-10 percent" class, and 2 percent were in the 75+ percent class.

Of the 3 aspect classes, 49 percent of the samples were classed as "southerly", 41 percent were "northerly", and the remaining 11 percent were classed as "flat".

3. <u>Vegetation</u>. Of the 17 SAF cover types that were identified, 5 types accounted for 75 percent of the samples: 1) lodgepole pine (24 percent), 2) ponderosa pine (17 percent), 3) western larch (12 percent), 4) interior Douglas-fir (11 percent), and 5) spruce/fir (11 percent). Table 1 lists the 17 SAF cover types and their respective frequencies.

Of the 15 habitat types (series level only) that were identified, 51 percent occurred in 2 types: subalpine fir (33 percent) and Interior Douglas-fir (18 percent). "Pacific silver fir" was the only other habitat type series which had a double-digit value (10 percent). As mentioned earlier, the predominance of these few types primarily reflects their broad ecological amplitudes, rather

than being the most frequently studied types. Table 2 lists the 15 habitat types and respective sample frequencies.

In terms of stand physical structure data, 61 percent of the stands were in the "highly mixed" structure category, 32 percent were in the "overmature" category, and 7 percent were in the "mature" category. None of the stands were classed as immature, reflecting the fact that the fire history studies generally did not examine young stands. For the understory, 57 percent of the stands were classed as "not dense" and 43 percent were classed as dense.

In terms of maximum stand age, 55 percent of the stands were between about 250 and 400 years old. Twenty-four percent were between 100 and 250 years old, 16 percent were between 400 and 1000 years old, and 5 percent were less than 100 years old.

For age class structure, 54 percent of the stands were classed as primarily even-aged, and the remaining 46 percent were uneven-aged. One important note here is that some stands for the coastal Douglas-fir cover type were entered into the primarily "even-aged" category (discussed later in the report)--studies indicated that some of these young- to moderate age stands had a primarily even-aged character because of major age class "pulses" of post-fire regeneration (converse to the oldest stands in the type, which were usually had a highly uneven-aged canopy because of long fire-free intervals). In terms of numbers of age classes per stand, 46 percent were highly mixed (i.e., "no age classes" [primarily uneven-aged stands]), 42 percent contained one age class (primarily even-aged stands), 10 percent contained 2 classes, and 2 percent contained 3 classes.

4. <u>Fire History</u>. Of the 4 possible fire scar classes, 33 percent of the stands had multiple-scarred trees, 29 percent had single-scarred trees, 25 percent of the stands had no fire scars, and 14 percent of the stands had primarily double-scarred trees.

For the fire severity class, 46 percent of the stands had primarily stand-replacing fires, 26 percent had fires of mixed severity, and the remaining 28 percent of the stands experienced primarily non-lethal surface fires.

Of the 3 possible fire spread classes, 55 percent of the stands experienced a primarily mixed spread pattern (i.e., primarily uniform spread but with substantial areas of patchy spread), 27 percent of the stands had uniformly spreading fires, and 18 percent of the stands had primarily non-uniformly spreading fires (i.e., primarily small patches).

In terms of fire sizes, 25 percent of the stands had no data on sizes from the literature, 19 percent of the stands occurred in areas which had fires ranging primarily from 1000 to 5000 acres, 20 percent of the fires ranged from 5000 to 10,000 acres, 18 percent ranged from 200 to 1000 acres, 12 percent ranged from 10,000 to 50,000 acres, 3 percent exceeded 50,000 acres, and 2 percent of the stands occurred in areas which had fires that were primarily less than 200 acres each. As described earlier, however, these data are considered to be highly speculative and not particularly meaningful for developing a fire regimes classification because we focused on the stand level of analysis. Still, the data might be useful for describing large study areas that are composed of moist forest types, where fires have been primarily large and where the data (from forest mosaic mapping) is most reliable.

Statistical Analysis. The first step in the statistical analysis was to define which dependent variables constitute a "fire regime." Kilgore (1987) felt that the a fire regime consists of the following factors: 1) fire type and fire intensity (i.e., what I have termed "fire severity"), 2) fire frequency, 3) size of area burned, 4) typical season of burning, 5) pattern of burn, and 6) what he termed fire severity and depth of burn (i.e., quantitative thermodynamic effects). I chose to define "fire severity" to be the cumulative

effects of fire in the stand (e.g., non-lethal surface fires or stand-replacing fires) because I feel that the term is a better descriptor ("intensity" often refers to quantifiable thermodynamic effects [Romme et al. 1980]). Heinselman (1978, 1981) and Kilgore (1981) felt that the most important fire regime descriptors from the standpoint of planning and management are what I have termed fire "severity", and fire frequency. Judging from the quality of the various categories of data in the literature review, I feel that the most realistic fire regime descriptors are: 1) fire severity, 2) fire frequency as reflected by MFI, and 3) fire spread pattern. These descriptors therefore constituted the major dependent variables in the statistical analysis.

In addition to testing each independent variable's contribution to the variance of the dependent variables, a major goal in the study was to explore any statistically-significant combinations of variables. Thus, the first step in the a priori analysis was to determine possibly significant combinations of fire severity and fire spread, and these were called "fire regime" types. Five combinations were possible from the literature review data base: 1) non-lethal severity/non-uniform spread, 2) non-lethal severity/uniform spread, 3) mixed severity/non-uniform spread, 4) lethal severity/non-uniform spread, 5) lethal severity/uniform spread. The sample frequency distribution indicated that 36 percent of the sample stands experienced fires which had primarily a "mixed severity/non-uniform (patchy) spread" pattern; 31 percent had a "lethal severity/non-uniform spread" pattern; 17 percent had a "lethal severity /uniform spread" pattern; 10 percent had a "non-lethal severity/uniform spread" pattern; and the remaining 6 percent of stands had a "non-lethal/non-uniform" pattern. These severity/spread and MFI variables would later be examined relative to the classes of independent variables discussed below.

The second step was to attempt to identify which independent variables would be potentially major contributors to the variation in MFI between the 5 fire

regime types. Each variable would be tested alone (one-way ANOVA) but a major goal also was to test potentially important combinations of these variables. The most significant combinations were hypothesized to be: 1) precipitation, 2) habitat type, and 3) cover type. A data class was established, for statistical examination, which might successfully reflect both moisture and vegetation. The rationale was that the most-useful classification would describe a combination of the above variables for a fire regime, since an area's vegetation is an integration of precipitation and site moisture.

The first step in classifying the vegetation data was to define a category called "stand types." This is simply a combination of habitat type series and SAF cover type, derived directly from the literature review data sheets (the method for classifying habitat type associations is addressed below). The stand types would be useful in the eventual classification key because they would: 1) delimit which cover types exist within a given habitat type, and 2) portray which forest cover types exist among multiple habitat types. Also, the stand types might be useful in compiling written descriptions of the fire regimes because the stand types portrayed the different stages of post-fire succession that occur within a given habitat type series.

The literature review data indicated that there were 45 stand types represented. The following labelling system was used for the stand types (presented in Table 3, over _ pages). The habitat type series is the first acronym appearing in the stand type label, according to the 4-letter tree species acronyms used by Pfister et al. (1977); the second acronym refers to the SAF cover type and is a simple abbreviation of the dominant tree species in the canopy (the tree species for both acronym categories were detailed in tables 1 and 2). Following are some examples of stand types: "ABLA/LARCH", "ABLA/LPP", "TSHE/WRC-WH" (western redcedar-western hemlock), and so on. Interestingly, 56 percent of the 387 samples were produced by 7 of the 45 stand

types, but "ABLA/LPP" was the only type which contributed a double-digit percentage to the total number (i.e., 16% of all samples)("PSME/INT PP" ranked second at 9 percent). Moreover, 35 of the 45 stand types (78%) had 20 or fewer samples and 26 of the 45 stand types (58%) had fewer than 10 samples each.

The next classification step was to attempt to account for site moisture variation, as reflected by the habitat type association, within each habitat type series. Three site moisture groups were subjectively defined in the following manner. The habitat type associations had to reflect similar moisture characteristics, that is, similar life forms and similar understory structure. Specifically, 3 "site moisture" categories were defined: 1) relatively dry sites within a given habitat type series (primarily grasses and scattered low shrubs), 2) moderately moist sites (primarily medium stocking of low- and medium-height tall shrubs), and 3) moist sites (primarily dense stocking of medium- and tall shrubs, or, an understory of moist-site ferns and forbs). A subjective rating of site moisture class was considered acceptible, for 3 reasons: 1) the site-specific data on precipitation were not considered to be highly reliable (discussed earlier), 2) I was not able to accurately estimate precipitation on such a refined level as individual habitat types, and 3) moreover, users of an eventual fire regimes key might be more easily able to derive a subjective estimate of site moisture for a given stand type.

The final classification step was to group any ecologically similar stands, called "habitat type groups". The limited data base for many of the stand types suggested that this subsequent grouping would be appropriate because it would, in effect, expand the data base for the final fire regime classification (some stand types only had 1 or 2 samples in the data base). That is, the statistical analysis would also test this relatively broad stratification of ecologically similar stands for significance in MFI. Each stand type with its appropriate site moisture class was thus assigned to one of three relatively

broad classes, called "habitat type groups" (table 3). The habitat type groups were subjectively defined in a manner similar to that for the site moisture analysis. That is, the stand types' series and associations had to reflect similar moisture characteristics, that is, similar tree series and similar association life forms and structure. Specifically, the habitat groups are: 1) "xeric" habitat types--represented by a relatively dry tree series usually with an open understory composed of grasses and scattered low shrubs, 2) "moderately moist" habitat types--represented by a relatively dry to moderately moist tree series usually with moderate stocking of medium-tall shrubs, and 3) "moist" habitat types--represented by a moderately moist to moist tree series usually with a generally dense stocking of medium and tall shrubs, or, moist-site forbs and ferns. Again, a subjective ecologically based estimate was considered acceptible.

The following chart illustrates this tri-level classification of the vegetation, using habitat type examples from Pfister et al. (1977):

Pfister H.T.	**Stand Type**	**Site Moist.**	**Hab. Type Group**
Pipo/Agsp	PIPO/INT PP	Dry	Xeric
Pipo/Putr	PIPO/INT PP	Dry	Xeric
Psme/Syal	PSME/INT PP	Mod.	Xeric
Pifl/Feid	PIFL/INT DF	Dry	Moderate
Psme/Caru	PSME/PIPO	Dry	Moderate
Psme/Phma	PSME/PIPO	Mod.	Moderate
Abla/Cage	ABLA/INT DF	Mod.	Moderate
Abla/Vaca	ABLA/INT DF	Mod.	Moderate
Abla/Vaca	ABLA/LPP	Moist	Moderate
Psme/Vagl	PSME/INT DF	Moist	Moderate
Abla/Mefe	ABLA/ES-SAF	Mod.	Moist
Abla/Vagl	ABLA/ES-SAF	Mod.	Moist
Abla/Xete	ABLA/ES-SAF	Mod.	Moist
Abla/Xete	ABLA/ES-SAF	Moist	Moist
Thpl/Clun	THPL/WRC-WH	Moist	Moist
Thpl/Opho	THPL/WRC	Moist	Moist

Note that in the classification no "Moist" site moisture class exists for the

"Xeric" habitat type groups, and no "Dry" site moisture class exists for the "Moist" habitat type groups. Table 3 presents the entire a priori vegetation classification resulting from the literature review.

In summary, in addition to statistical testing of each individual study variable, a major goal was to conduct testing of a priori groups of the following potentially significant classes of variables: 1) 5 "fire regime types" (combinations of fire severity and spread derived directly from the literature review data base), and 2) a 3-level stratification which portrayed the hypothesized integration of climate and site moisture by forest vegetation:

> Level 1. **Habitat type group**: A broad classification which groups ecologically similar "stand types" (defined below). The stand types were assigned to 1 of 3 habitat type groups (xeric-moderate-moist) by subjectively analyzing the vegetative indicators of relative moisture in both the tree and undergrowth layers.
>
> Level 2. **Site Moisture**: A broad classification which indicates possible site moisture variation within each habitat type group above. The stand types (below) were assigned to 1 of 3 site moisture groups (dry-moderate-moist) by subjectively relativizing the moisture traits of the tree series and the association life forms and understory structure within each habitat type group.
>
> Level 3. **Stand types**. The possible combinations of habitat type (series level only) and SAF cover type, derived directly from the literature data base. The literature review data produced 45 stand types.

The next step was to test the various classes of variables for statistical significance ($p < .01$). First, a one-way analysis of variance (ANOVA) was performed to determine each variable's contribution to the variance in mean fire interval (table 4). (As previously described, in addition to fire severities and spreads, MFI was considered to be a prime indicator of a fire regime). The next step was to test which of the above combinations of variables might account for significant amounts of the variance in mean fire interval.

The most-significant dependent variables (table 4) were found to be those relating to the fire regime itself; fire severity and fire spread. The most-significant independent variables were those reflecting the moisture regimes. For example, habitat group alone accounted for 38 percent of the variance in mean fire interval, and moisture class accounted for 34 percent. Table 4 illustrates that many of the variables, by themselves, were not strong predictors of the variance in mean fire interval. For example, the lowest F-ratios were produced for age structure, overstory structure, fire spread, slope class, and stand aspect. This well illustrates the rationale for the _a priori_ groupings of variables that reflect fire severity/spread and the integration of climate by vegetation. These groups did, in fact, explain most of the variation in MFI.

Additionally, a regression analysis of mean fire interval as a function of minimum and maximum site elevation resulted in r-square values of .00 and .01, respectively. A regression analysis of mean fire interval on annual precipitation and seasonal precipitation yielded r-square values of .31 and .26, respectively. However, elevation and precipitation is indirectly reflected by the _a priori_ vegetation classification (habitat group, site moisture, stand type). Moreover, elevation and precipitation would not, by themselves, be highly useful in constructing the fire regimes key--the groups of variables integrate as many useful data sources as possible and this was seen as the most useful approach for constructing the classification.

The next step was to examine the degree of correlation between the vegetation/moisture variables and the fire severity/spread class. A three-way ANOVA of habitat group, moisture class, and fire severity/spread class on mean fire interval yielded a highly significant F ratio of 82 ($p = 0.00$), explaining 64 percent of the variance. Conversely, the remaining variables contributed less than 1 percent of the variance to mean fire intervals, verifying our

initial hypothesis that the vegetation/moisture and fire regime variables would be the most useful descriptors in developing the fire regimes classification.

In summary, the fire regime information obtained from the literature is very well behaved. MFI typically increased in a predictable manner with habitat moisture class, site moisture class, and annual and seasonal precipitation (figs. 1-2)(Appendix E presents the estimated precipitation data for the fire regime/vegetation groups). The few anomalies (outliers) in the data, that is, stands whose mean fire intervals were on the extremes for their habitat group, probably reflect pockets of habitat/cover types occurring within a larger area of substantially different vegetation and fire regime characteristics.

Fire Regimes Classification: Structure and Use. In terms of producing a useful fire regimes classification, we had felt that the most useful type of key would contain easily identifiable independent variables. During the initial stages of the data analysis, it was hypothesized that the vegetation classification groups described above (habitat group, site moisture, and stand type) might be the potentially most-useful descriptors. These did, in fact, prove to be the most powerful descriptors of fire regime (i.e., MFI/severity/spread). Therefore, the combinations of these variables constitute the proposed fire regimes classification, which is presented in its entirety in table 5 (Appendix F also displays which literature review references supplied the data for each stand type in the classification). The classification is a 4-level stratification. The first level is "Habitat groups", that is, the groups of ecologically similiar stand types. The second level is site "Moisture type" (dry-moderate-moist). The third level is the fire regime (i.e., 5 possible combinations of severity/spread) and the final level is the 45 stand types that were sampled in Pacific Northwest forests. Finally, MFI is displayed for each of these four levels of stratification.

Figure 3 presents an example of how the fire regimes classification might be presented in a useful diagnostic format such as a key. A branched "decision tree" format was used in this case. By correctly diagnosing stand type and the site's overall moisture characteristics, a user should be able to estimate which fire regime type was characteristic during the presettlement era (the listed stand types will help guide the user into the appropriate habitat type and site moisture groups). Note that the key can be designed to include various degrees of detail. For example, it might consist of just broad descriptors, such as severity/spread/MFI, or it might also include information on the possible minimum and maximum fire suppression factor for the stands, or mean annual or mean fire season precipitation values (fig. 3).

Figure 3 presents 2 examples from the suggested key (Appendix G displays this key for the entire fire regimes classification). The first example is for "xeric habitat types"/"dry sites" and displays the stand types that were considered to occupy this class (e.g., dry ponderosa pine/Douglas-fir stands). The second example is for "moist habitat types"/"moist sites" and displays the stand types that were considered to occupy this class (e.g., moist western hemlock and pacific silver fir stands). To utilize the key (fig. 3), the user first identifies the appropriate stand type (i.e., habitat type series plus cover type) for the stand. The user then refers to the key to see which habitat type group contains that stand type. The next step is to select the appropriate site moisture group by subjectively estimating if that standtype occurs along the along the dry, moderate, or moist end of the site moisture gradient (in the classification, stand types usually occupy just 1 or at most 2 site moisture categories, thus it should be relatively easy for the user to select the appropriate category). A subjective estimate is recommended here because the precipitation data for the categories are not considered sufficiently reliable to provide highly refined diagnostics. If the user has

precipitation data for the stands, however, the mean annual values might be checked for general agreement with those for the classification's site moisture categories because the mean annual precipitation values generally increased according to progressively more-moist vegetation (the data on mean fire season precipitation probably is a less useful indicator because there is substantially less variation due to regional summer drought)(Appendix E).

Depending on the user's goals, he could simply stop at the "Habitats" level of description since an MFI for all of the stand types occurring across the range of possible site moistures is provided at this first level. Or, the user might choose to stop at the "site moisture" level of analysis since this branch of the key also provides information on MFI for all sample stands within that category. If the user desired more-detailed descriptions of the fire regime, such as the likely fire severities and spreads, he would progress all the way through the key.

To obtain this information, the user would continue on to the next level of the key which portrays the 5 possible fire regimes. Once the correct diagnosis of stand type and site moisture type has been made, the detailed fire regimes information can be determined for that stand type. This level indicates the range of fire severities, fire spreads, mean fire intervals, and fire "suppression factor" values that were found in the literature for those stand types. (Note: the fire suppression factors may have some value in suggesting possible fire frequency changes during the fire suppression period, but the factors are not statistically valid indicators because nearly all of the stands in the literature review have not experienced fires over the last 50 years). A rough estimate of the probability of a given fire regime occurring in these stand types can be derived by examining the number of samples that were found for each fire regime category.

The following hypothetical example is presented to specifically illustrate the key's use (fig. 3). Assume that the user wishes to describe the possible fire regimes for an area consisting of ponderosa pine/juniper cover types. He also knows that the habitat types would be primarily ponderosa pine. The key first lists this stand type under the "xeric" habitat group, and the literature indicated that all such xeric stand types had an MFI of about 14 years (mean MFI from 52 samples). The key then directs the user to the the xeric site moisture class because these stand types reflect the dry end of the moisture gradient within this habitat group. At this point the key suggests that all such stands had a combined MFI of about 13 years. (The key also suggests a mean annual precipitation of about 16 inches and a mean fire season value of 1 inch but, in retrospect, the annual value might be a slight overestimate). To examine possible fire regime variability within this xeric site moisture group, the user would proceed to the final segment of the key. The literature indicated 2 possible fire regimes for these dry stand types: 1) Fire Regime 1 (non-lethal severity/non-uniform spread); MFI was about 12 years; the possible fire suppression factor ranged from 2 to 8 times greater than the pre-suppression individual fire interval values; or 2) Fire Regime 2 (non-lethal severity/uniform spread); MFI was about 14 years; fire suppression factor ranged from 1.3 to 16 times greater than the pre-suppression fire interval values. Also, the probability of either fire regime occurring might be estimated by examining the number of samples that were found for each fire regime type. In this case Fire Regime 2 was found in 27 of the 39 stands (approximately 69% probability) and Fire Regime 1 occurred in the remaining 12 samples (31%). Note, however, that this may not be a highly valid measure of probability because the fire history studies might not represent a truly random sample across the landscape.

Conclusion/Recommendations

In summary, a fire regimes classification was developed by first defining 5 possible "fire regimes", which are a combination of 3 important fire history variables for which reliable data exists (frequency/severity/spread). The most-significant classes of independent variables that helped predict the possible fire regime types were the forest vegetation's integration of climate. A 4-level classification was developed which first classified vegetation into 3 broad habitat type groups, then into 3 possible site moisture classes and finally into 45 stand types which reflect combinations of climax vegetation and forest cover types in the Pacific Northwest. These relatively broad classification categories, when combined, were seen as the most useful format for diagnosing fire regime types, for 2 reasons: 1) a more-highly refined classification was not possible because the quality and amount of the data for many categories of the literature review data base was limited, and 2) a relatively broad fire regimes classification probably would be the most useful format for most management purposes.

Many avenues remain to be explored in terms of future development of the system. At this point, however, the most logical next step would be to identify the most valuable aspects of the fire regimes classification, and which potential problems, if any, need to be addressed.

If the current classification format seems acceptible, the system should be further refined by determining which specific forest habitat types in the Northwest might apply to the various categories within the classification (there are perhaps several hundred specific habitat types in the region). This would include a final subjective "testing" and refinement of the system, that is, an evaluation of how well the numerous habitat types fit into the system. Next, a comprehensive cataloging of the fire history/ecology of major vegetation categories within the classification should be prepared. That is,

the fire regimes would need to be more highly detailed beyond just the broad fire regime descriptors. These descriptions would also need to include a discussion of the possible effects of fire suppression within the various vegetation types.

After this fine-tuning of the classification, the next logical phase would be to explore possible uses of the system. For example, the classification might be useful to researchers because it would a represent a standard reporting language for organizing the various fire ecology studies in the Northwest. The classification also would help define which forest types lack detailed data and require further study in terms of fire history and fire effects.

There are many potentially useful applications of the fire regimes system for forest management. For example, the classification could serve as a comprehensive fire ecology reference source for managers. Various diagnostic uses of the classification also need to be explored in detail. For example, it probably could have useful applications for various aspects of fire planning and vegetation mapping, and the classification might also be used in tandem with other classifications such as those for vegetation or wildlife habitat. At this point, however, potential applications of fire regimes classifications are ambiguous and researchers such as M. Heinselman, B. Kilgore, and others might be consulted for any helpful insights.

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Table 1. The literature review's 17 SAF cover types (Eyre 1980) and sample frequency distribution.

SAF Type	(Code)	Spp. Names	Frequency	Percent
ES/SAF	(206)	Picea englem./A. lasiocarpa	42	10.9
WHITEBARK	(208)	Pinus albicaulis	11	2.8
INT DF	(210)	Pseudo. menziesii (var. glauca)	42	10.9
WHITE FIR	(211)	A. concolor	2	.5
W.LARCH	(212)	Larix occidentalis	45	11.6
GRAND FIR	(213)	A. grandis	2	.5
W.WHITE	(215)	Pinus monticola	7	1.8
ASPEN	(217)	Populus tremuloides	4	1.0
LODGEPOLE	(218)	Pinus contorta (var. latifolia)	92	23.8
W.HEMLOCK	(224)	Tsuga heterophylla	1	.3
FIR-WH	(226)	Coastal Abies spp./Tsuga heter.	26	6.7
WRC-WH	(227)	Thuja plicata/Tsuga heter.	6	1.6
W.R.CEDAR	(228)	Thuja plicata	5	1.3
PAC DF	(229)	Pseudo. menziesii (var. menz.)	12	3.1
DF-WH	(230)	Psdo. menz. (menz.)/Tsuga heter.	22	5.7
INT PP	(237)	Pinus ponderosa	66	17.1
JUNIPER	(238)	Juniperus spp.	2	.5
TOTALS			387	100.0

Table 2. The literature review's 15 habitat type series and sample frequency distribution.

Habitat Type Series	Frequency	Percent
ABAM (*Abies amabilis*)	40	10.3
ABCO (*A. concolor*)	10	2.6
ABGR (*A. grandis*)	25	6.5
ABLA (*A. lasiocarpa*)	126	32.6
ABMA (*A. magnifica*)	3	.8
LALY (*Larix lyallii*)	4	1.0
PIAL (*Pinus albicaulis*)	6	1.6
PICE (*Picea* spp.)	18	4.7
PICO (*Pinus contorta* [*latif.*])	6	1.6
PIFL (*Pinus flexilis*)	2	.5
PIPO (*Pinus ponderosa*)	18	4.7
PSME (*Pseudo. menz.* [*glauca*])	68	17.6
THPL (*Thuja plicata*)	34	8.8
TSHE (*Tsuga heterophylla*)	26	6.7
TSME (*Tsuga mertensiana*)	1	.3
TOTALS	387	100.0

Table 3. Tri-level vegetation classification: sample frequency distribution for the pre-Fire Suppression Period by habitat group, site moisture class, and stand type.

Classification		Frequency	
HABGROUP	**XERIC HABITATS**	**52**	**TOTAL (13% of population)**
MOISTURE	**DRY SITES**	**39**	**SUBTOTAL**
STANDTYP	PIPO/INT PP	16	
STANDTYP	PIPO/JUNIP	2	
STANDTYP	PSME/INT PP	21	
MOISTURE	**MODERATE SITES**	**13**	**SUBTOTAL**
STANDTYP	PSME/INT PP	13	
HABGROUP	**MODERATE HABITATS**	**139**	**TOTAL (36% of population)**
MOISTURE	**DRY SITES**	**26**	**SUBTOTAL**
STANDTYP	ABCO/WF	1	
STANDTYP	ABCO/INT PP	1	
STANDTYP	ABGR/INT PP	4	
STANDTYP	ABLA/INT DF	4	
STANDTYP	PIFL/INT DF	2	
STANDTYP	PSME/INT DF	13	
STANDTYP	PSME/ASPEN	1	
MOISTURE	**MODERATE SITES**	**90**	**SUBTOTAL**
STANDTYP	ABAM/INT PP	2	
STANDTYP	ABCO/INT DF	4	
STANDTYP	ABCO/WF	1	
STANDTYP	ABCO/INT PP	3	
STANDTYP	ABGR/INT DF	4	
STANDTYP	ABGR/INT PP	6	
STANDTYP	ABLA/INT DF	1	
STANDTYP	ABLA/ASPEN	1	
STANDTYP	ABLA/LPP	40	
STANDTYP	ABMA/LPP	3	
STANDTYP	PICO/LPP	6	
STANDTYP	PSME/INT DF	13	
STANDTYP	PSME/LARCH	1	
STANDTYP	PSME/ASPEN	2	
STANDTYP	PSME/LPP	3	
MOISTURE	**MOIST SITES**	**23**	**SUBTOTAL**
STANDTYP	ABLA/LPP	22	
STANDTYP	PSME/INT DF	1	

Table 3. (cont.)

Classification		Frequency	
HABGROUP	**MOIST HABITATS**	**196**	**TOTAL (51% of population)**
MOISTURE	**MODERATE SITES**	**28**	**SUBTOTAL**
STANDTYP	ABGR/LARCH	1	
STANDTYP	ABLA/ES-SAF	19	
STANDTYP	PIAL/ES-SAF	2	
STANDTYP	PICE/LARCH	1	
STANDTYP	PICE/LPP	4	
STANDTYP	TSME/LPP	1	
MOISTURE	**MOIST SITES**	**168**	**SUBTOTAL**
STANDTYP	ABAM/ES-SAF	6	
STANDTYP	ABAM/FIR-WH	22	
STANDTYP	ABAM/PAC DF	10	
STANDTYP	ABGR/LARCH	8	
STANDTYP	ABGR/GF	2	
STANDTYP	ABLA/ES-SAF	15	
STANDTYP	ABLA/WBP	3	
STANDTYP	ABLA/LARCH	19	
STANDTYP	ABLA/FIR-WH	2	
STANDTYP	LALY/WBP	4	
STANDTYP	PIAL/WBP	4	
STANDTYP	PICE/LPP	13	
STANDTYP	THPL/LARCH	14	
STANDTYP	THPL/WWP	7	
STANDTYP	THPL/WRC-WH	5	
STANDTYP	THPL/WRC	5	
STANDTYP	THPL/DF-WH	3	
STANDTYP	TSHE/LARCH	1	
STANDTYP	TSHE/WH	1	
STANDTYP	TSHE/FIR-WH	2	
STANDTYP	TSHE/WRC-WH	1	
STANDTYP	TSHE/PAC DF	2	
STANDTYP	TSHE/DF-WH	19	
	POPULATION:	387	

Table 4. ANOVA Results of 19 Variables with Mean Fire Interval, ranked according to F Ratio.

Variable	F Ratio
Severity	300
Fire Scars	187
Habitat Group	121
Moisture	101
Understory	97
Fire Regime Type	75
SAF Type	40
Habitat Type	30
Fire Size	26
Stand Type	20
Region	19
Surface Form	18
Dissection	16
State	16
Aspect	13
Slope	6
Spread	5
Overstory	3
Age Structure	1

Table 5. Fire Regimes Classification: Pre-Fire Suppression Period mean MFIs stratified according to Habitat Group, Site Moisture Class, Fire Regime Type, and Stand Type. Following pages present xeric-to-moist habitat type groups.

Classification		MFI (Mean)	Std Dev	Frequency
HABGROUP	XERIC HABITATS	14.4038	7.8197	52
MOISTURE	DRY SITES	13.1795	4.9782	39
FIREREGM	**NONLETHAL-NONUNIFORM**	**12.3333**	**2.6054**	**12**
STANDTYP	PIPO/INT PP	11.0000	2.3094	4
STANDTYP	PSME/INT PP	13.0000	2.6186	8
FIREREGM	**NONLETHAL-UNIFORM**	**13.5556**	**5.7334**	**27**
STANDTYP	PIPO/INT PP	14.1667	6.5204	12
STANDTYP	PIPO/JUNIP	8.0000	0.0	2
STANDTYP	PSME/INT PP	13.8462	5.1615	13
MOISTURE	MODERATE SITES	18.0769	12.7244	13
FIREREGM	**NONLETHAL-NONUNIFORM**	**17.0000**	**6.2849**	**9**
STANDTYP	PSME/INT PP	17.0000	6.2849	9
FIREREGM	**NONLETHAL-UNIFORM**	**20.5000**	**23.0434**	**4**
STANDTYP	PSME/INT PP	20.5000	23.0434	4

Table 5 (cont.)--Fire Regimes Classification for moderate habitat type groups.

Classification		MFI (mean)	Std Dev	Frequency
HABGROUP	MODERATE HABITATS	89.4604	91.0167	139
MOISTURE	DRY SITES	28.8462	18.1586	26
FIREREGM	**NONLETHAL-NONUNIFORM**	**16.5000**	**1.7321**	**4**
STANDTYP	ABCO/WF	18.0000	0.0	1
STANDTYP	ABCO/INT PP	18.0000	0.0	1
STANDTYP	ABGR/INT PP	15.0000	0.0	2
FIREREGM	**NONLETHAL-UNIFORM**	**28.2857**	**13.9253**	**21**
STANDTYP	ABGR/INT PP	20.0000	0.0	2
STANDTYP	ABLA/INT DF	41.0000	0.0	3
STANDTYP	PIFL/INT DF	38.0000	0.0	2
STANDTYP	PSME/INT DF	24.3846	15.2071	13
STANDTYP	PSME/ASPEN	38.0000	0.0	1
FIREREGM	**MIXED-NONUNIFORM**	**90.0000**	**0.0**	**1**
STANDTYP	ABLA/INT DF	90.0000	0.0	1
MOISTURE	MODERATE SITES	94.7222	94.5629	90
FIREREGM	**NONLETHAL-NONUNIFORM**	**18.1429**	**6.8259**	**14**
STANDTYP	ABCO/WF	31.0000	0.0	1
STANDTYP	ABCO/INT PP	14.3333	.5774	3
STANDTYP	ABGR/INT PP	15.0000	0.0	1
STANDTYP	ABLA/LPP	17.0000	0.0	1
STANDTYP	ABMA/LPP	31.0000	0.0	1
STANDTYP	PSME/INT DF	16.6667	6.4083	6
STANDTYP	PSME/LARCH	17.0000	0.0	1
FIREREGM	**NONLETHAL-UNIFORM**	**17.3571**	**15.4153**	**14**
STANDTYP	ABAM/INT PP	11.0000	0.0	2
STANDTYP	ABCO/INT DF	10.0000	0.0	4
STANDTYP	ABGR/INT DF	55.0000	0.0	1
STANDTYP	ABGR/INT PP	15.5000	5.1962	4
STANDTYP	ABLA/INT DF	50.0000	0.0	1
STANDTYP	PSME/INT DF	7.0000	0.0	2
FIREREGM	**MIXED-NONUNIFORM**	**73.0256**	**29.8941**	**39**
STANDTYP	ABGR/INT DF	42.3333	13.2791	3
STANDTYP	ABGR/INT PP	50.0000	0.0	1
STANDTYP	ABLA/ASPEN	60.0000	0.0	1
STANDTYP	ABLA/LPP	93.0556	29.7113	18
STANDTYP	ABMA/LPP	50.0000	0.0	2
STANDTYP	PICO/LPP	50.0000	0.0	4
STANDTYP	PSME/INT DF	57.0000	27.3861	5
STANDTYP	PSME/ASPEN	60.0000	0.0	2
STANDTYP	PSME/LPP	77.0000	0.0	3
FIREREGM	**LETHAL-NONUNIFORM**	**248.5714**	**107.0124**	**14**
STANDTYP	ABLA/LPP	231.6667	106.5435	12
STANDTYP	PICO/LPP	350.0000	0.0	2

Table 5 (cont.)--Fire Regimes for moderate habitat type groups (cont.).

Classification		MFI (mean)	Std Dev	Frequency
MOISTURE	MODERATE SITES (cont.)			
FIREREGM	**LETHAL-UNIFORM**	**188.8889**	**41.6667**	**9**
STANDTYP	ABLA/LPP	188.8889	41.6667	9
MOISTURE	MOIST SITES	137.3913	92.5020	23
FIREREGM	**MIXED-NONUNIFORM**	**71.5455**	**46.8431**	**11**
STANDTYP	ABLA/LPP	68.4000	48.1368	10
STANDTYP	PSME/INT DF	103.0000	0.0	1
FIREREGM	**LETHAL-NONUNIFORM**	**275.0000**	**129.9038**	**3**
STANDTYP	ABLA/LPP	275.0000	129.9038	3
FIREREGM	**LETHAL-UNIFORM**	**172.0000**	**46.4650**	**9**
STANDTYP	ABLA/LPP	172.0000	46.4650	9

Table 5 (cont.)--Fire Regimes Classification for moist habitat type groups.

Classification		MFI (mean)	Std Dev	Frequency
HABGROUP	MOIST HABITATS	226.4388	124.1895	196
MOISTURE	MODERATE SITES	185.8929	117.0958	28
FIREREGM	**NONLETHAL-NONUNIFORM**	**27.0000**	**0.0**	**1**
STANDTYP	PICE/LARCH	27.0000	0.0	1
FIREREGM	**NONLETHAL-UNIFORM**	**38.0000**	**0.0**	**2**
STANDTYP	ABLA/ES-SAF	38.0000	0.0	2
FIREREGM	**MIXED-NONUNIFORM**	**74.5714**	**37.2776**	**7**
STANDTYP	ABGR/LARCH	17.0000	0.0	1
STANDTYP	ABLA/ES-SAF	120.0000	0.0	2
STANDTYP	PICE/LPP	71.6667	11.5470	3
STANDTYP	TSME/LPP	50.0000	0.0	1
FIREREGM	**LETHAL-NONUNIFORM**	**298.3333**	**66.6515**	**12**
STANDTYP	ABLA/ES-SAF	305.5556	42.8985	9
STANDTYP	PIAL/ES-SAF	350.0000	0.0	2
STANDTYP	PICE/LPP	130.0000	0.0	1
FIREREGM	**LETHAL-UNIFORM**	**166.6667**	**25.8199**	**6**
STANDTYP	ABLA/ES-SAF	166.6667	25.8199	6
MOISTURE	MOIST SITES	233.1964	124.3806	168
FIREREGM	**MIXED-NONUNIFORM**	**134.9545**	**84.3991**	**44**
STANDTYP	ABAM/FIR-WH	219.6667	124.4519	6
STANDTYP	ABAM/PAC DF	90.3333	24.2707	6
STANDTYP	ABGR/LARCH	113.0000	38.3406	5
STANDTYP	ABGR/GF	85.0000	0.0	2
STANDTYP	ABLA/ES-SAF	200.0000	0.0	1
STANDTYP	ABLA/WBP	200.0000	0.0	1
STANDTYP	ABLA/LARCH	177.5000	25.9808	4
STANDTYP	LALY/WBP	275.0000	0.0	2
STANDTYP	PIAL/WBP	151.5000	142.6055	4
STANDTYP	THPL/LARCH	85.0000	0.0	8
STANDTYP	THPL/WRC	85.0000	0.0	1
STANDTYP	TSHE/PAC DF	106.0000	0.0	2
STANDTYP	TSHE/DF-WH	50.0000	0.0	2
FIREREGM	**LETHAL-NONUNIFORM**	**266.1705**	**132.6781**	**88**
STANDTYP	ABAM/ES-SAF	306.0000	0.0	6
STANDTYP	ABAM/FIR-WH	378.7500	152.9189	16
STANDTYP	ABAM/PAC DF	177.0000	0.0	4
STANDTYP	ABGR/LARCH	200.0000	66.1438	3
STANDTYP	ABLA/ES-SAF	274.3333	77.1535	6
STANDTYP	ABLA/WBP	350.0000	0.0	2
STANDTYP	ABLA/LARCH	120.0000	2.4495	6
STANDTYP	LALY/WBP	325.0000	0.0	2
STANDTYP	PICE/LPP	113.3846	4.9923	13

STANDTYP	THPL/LARCH	212.5000	20.9165	6
STANDTYP	THPL/WWP	207.1429	18.8982	7

Table 5 (cont.)--Fire Regimes for moist habitat type groups (cont.)

Classification		MFI (mean)	Std Dev	Frequency
HABGROUP	MOIST HABITAT TYPES (cont.)			
MOISTURE	MOIST SITES (cont.)			
FIREREGM	**LETHAL NONUNIFORM (cont.)**			
STANDTYP	THPL/WRC-WH	377.2000	120.0383	5
STANDTYP	THPL/WRC	282.5000	20.2073	4
STANDTYP	TSHE/WH	550.0000	0.0	1
STANDTYP	TSHE/FIR-WH	550.0000	0.0	2
STANDTYP	TSHE/WRC-WH	306.0000	0.0	1
STANDTYP	TSHE/DF-WH	333.0000	31.1769	4
FIREREGM	**LETHAL-UNIFORM**	**272.6667**	**69.5598**	**36**
STANDTYP	ABLA/ES-SAF	231.2500	22.1601	8
STANDTYP	ABLA/LARCH	268.4444	81.8033	9
STANDTYP	ABLA/FIR-WH	250.0000	0.0	2
STANDTYP	THPL/DF-WH	200.0000	0.0	3
STANDTYP	TSHE/LARCH	350.0000	0.0	1
STANDTYP	TSHE/DF-WH	315.3846	65.7794	13
Entire Population		**148.7494**	**132.3750**	**387**

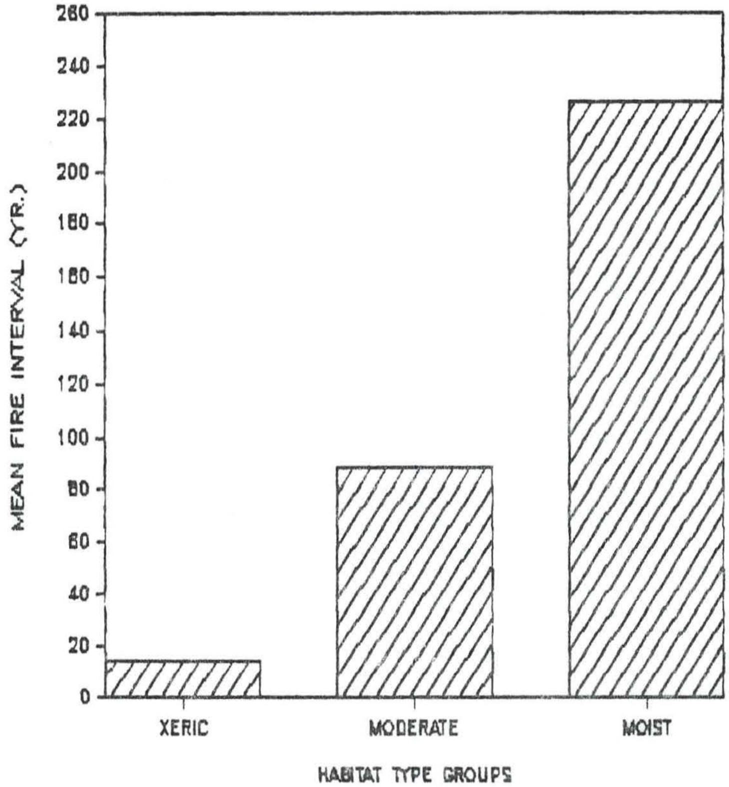
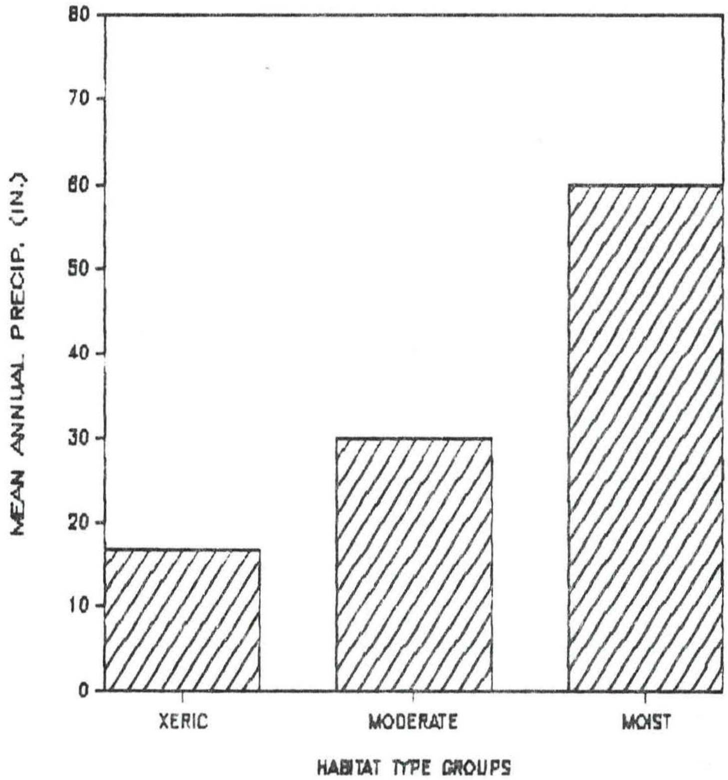


Figure 1. Mean Fire Interval and Mean Annual Precipitation for 3 habitat type groups.



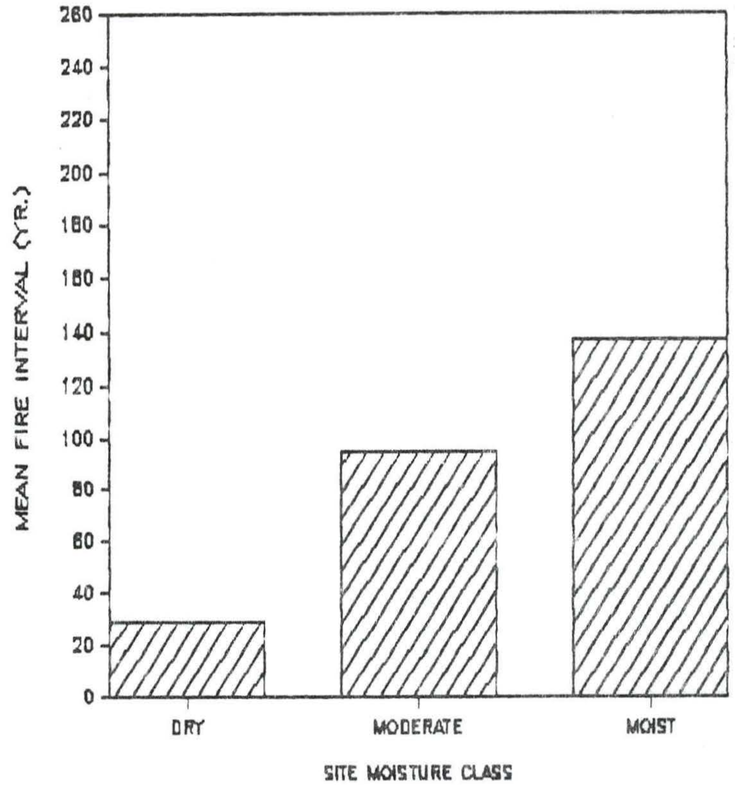
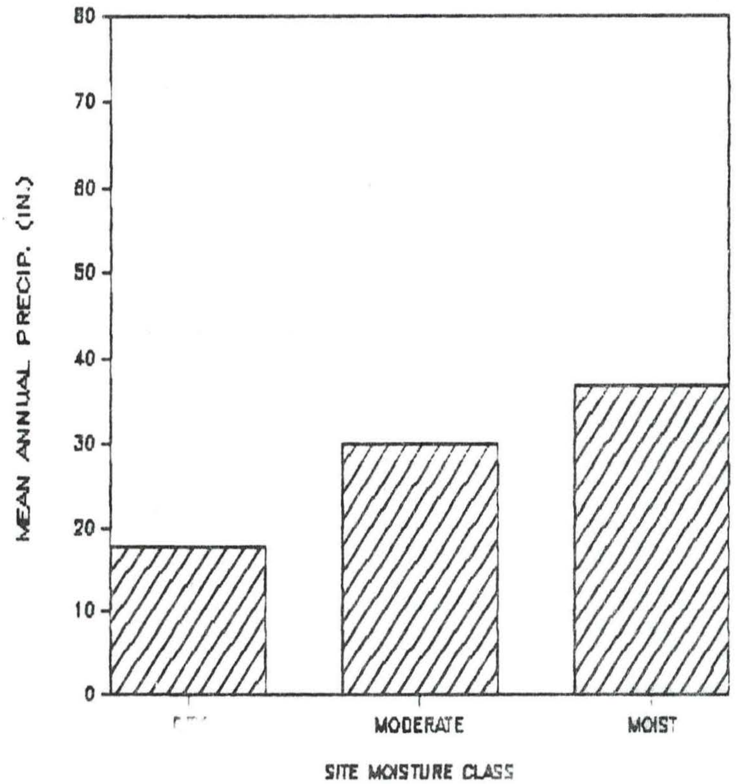


Figure 2. Mean Fire Interval and Mean Annual Precipitation according to the 3 site moisture classes within the Moderate habitat type group.



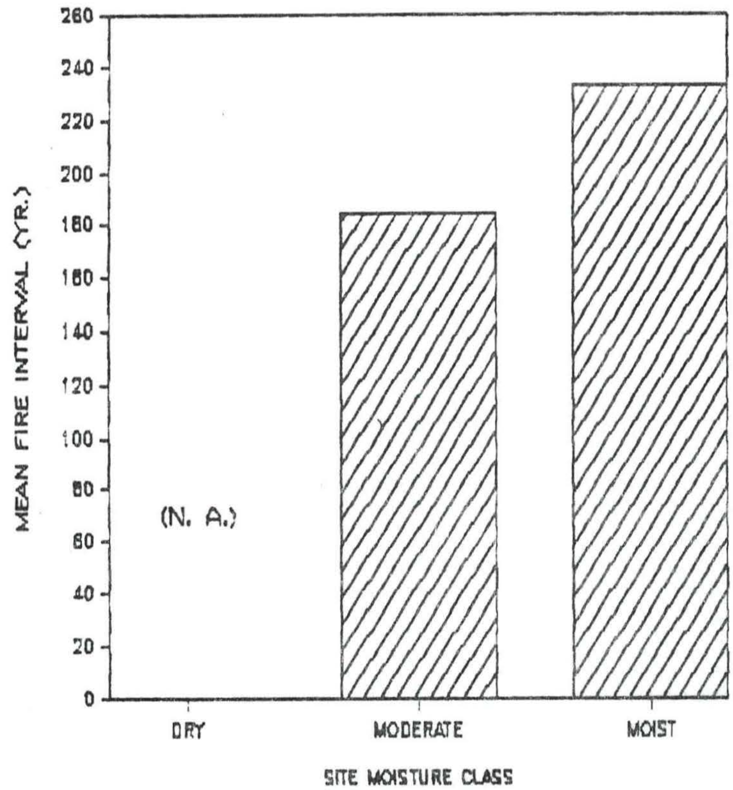


Figure 2 (cont.). Mean Fire Interval and Mean Annual Precipitation according to the 2 site moisture classes within the Moist habitat type group.

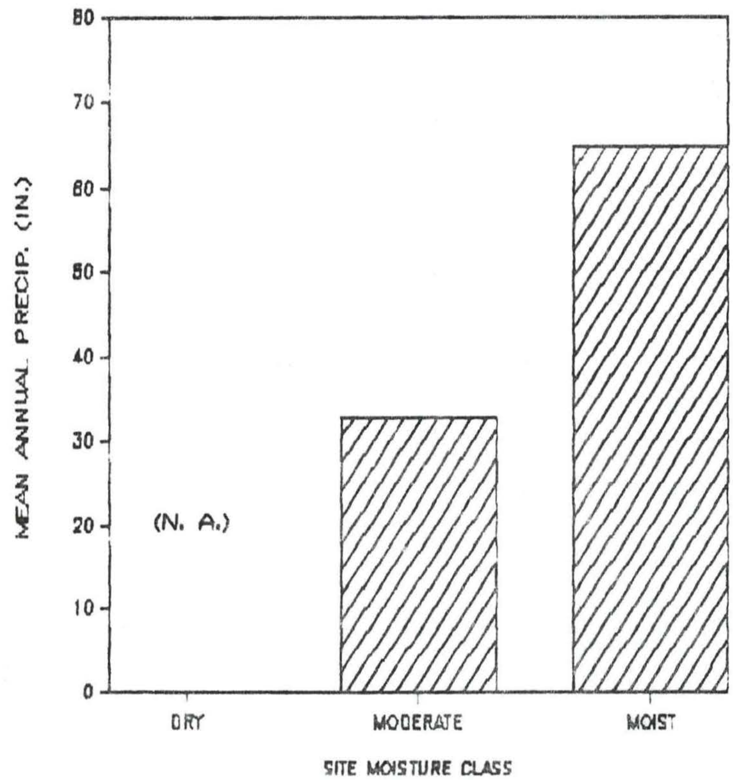


Figure 3. Example of fire regimes key for xeric habitats, dry sites.

XERIC HABITATS | DRY SITES | FIRE REGIME

Habitats

PIPO/JUNIP
PIPO/INT PP
PSME/INT PP

MFI 14.4
Samples 52

Moisture : Dry

Mean Fire Int : 13.2
Annual Precip : 16.4
Seasonal Precip: 1.1
Samples : 39

Severity : Non-Lethal
Spread : Non-Uniform

Mean Fire Int : 12.3
Sup Min Factor : 2.1
Sup Max Factor : 7.5
Samples : 12

Severity : Non-Lethal
Spread : Uniform

Mean Fire Int : 13.6
Sup Min Factor : 1.3
Sup Max Factor : 16.3
Samples : 27

Severity : Mixed
Spread : Non-Uniform

Mean Fire Int :
Sup Min Factor :
Sup Max Factor :
Samples : 0

Severity : Lethal
Spread : Non-Uniform

Mean Fire Int :
Sup Min Factor :
Sup Max Factor :
Samples : 0

Severity : Lethal
Spread : Uniform

Mean Fire Int :
Sup Min Factor :
Sup Max Factor :
Samples : 0

Fig. 3 (cont.)--Example of fire regimes key for moist habitats, moist sites.

MOIST HABITATS | MOIST SITES | FIRE REGIME

Habitats

ABAM/ES-SAF
/FIR-WH
/PAC DF
ABGR/GF
/LARCH
ABLA/ES-SAF
/FIR-WH
/LARCH
/WBP
LALY/WBP
PIAL/ES-SAF
/WBP
PICE/LARCH
/LPP
PSME/DF-WH
/FIR-WH
/PAC DF
THPL/DF-WH
/LARCH
/WRC
/WRC-WH
/WWP
TSHE/DF-WH
/FIR-WH
/LARCH
/LPP
/PAC DF
/WH

MFI 226.4
Samples 196

Moisture : Moist

Mean Fire Int : 233.2
Annual Precip : 64.7
Seasonal Precip: 3.0
Samples : 168

Severity : Non-Lethal
Spread : Non-Uniform

Mean Fire Int :
Sup Min Factor :
Sup Max Factor :
Samples : 0

Severity : Non-Lethal
Spread : Uniform

Mean Fire Int :
Sup Min Factor :
Sup Max Factor :
Samples : 0

Severity : Mixed
Spread : Non-Uniform

Mean Fire Int : 135.0
Sup Min Factor : 1.0
Sup Max Factor : 3.0
Samples : 44

Severity : Lethal
Spread : Non-Uniform

Mean Fire Int : 266.2
Sup Min Factor : 1.0
Sup Max Factor : 1.1
Samples : 88

Severity : Lethal
Spread : Uniform

Mean Fire Int : 272.7
Sup Min Factor : 1.0
Sup Max Factor : 1.0
Samples : 36

APPENDIX A
Literature review data sheet

REFERENCE:____

LOCATION. State:____ Specific:________________________________

	PRE-SUPPRESSION	SUPPRESSION
VEGETATION/TOPOGRAPHY		
Area Surface Form :		
Sample Unit/size :		
Cover Type :		
Hab. Type (ref.) :		
Phys. Struct.(code) :		
Age Struct.(code) :		
H.T. Elev. (range, ft):		
H.T. Slope (code) :		
H.T. Dissection (code):		
H.T. Aspect (N,S,flat):		
FIRE HISTORY		
F. Scars		
Single sc. :		
Double. sc. :		
Multiple sc. :		
Post-f. regen. :		
Scars & regen. :		
No. yrs. record :		
F. Supp. onset :		
Min. Intervals :		
Max. Intervals :		
MFI :		
% Intvl. Change (code):		
Severity (code) :		
Sizes (code)		
Surface fires :		
Std. Repl. fires :		
Spreads (code)		
Surface fires :		
Std. Repl. fires :		

CLIMATE: Pct. (mean, in.)	Wind Dir. (cardinal)	Velocity (mph)
Annual :_____	Annual :_____	Ann. :_____
F. Season:_____	F. Season:_____	F. S.:_____

Source/station:____

COMMENTS:

APPENDIX A (cont.)

Code list for literature review data sheets

Surface Form

a. Smooth plain
b. Irregular plain
c. Rough plain
d. Plateau (tableland)
e. Hills with narrow valleys
f. Open hills (hills with broad valleys)
g. Mountains with narrow valleys
h. Mountains with broad valleys
i. Plateau-like mountains
j. Plains with mountains (Basin & Range)

Physical Structure (list ages)

a. Immature
b. Mature
c. Over-mature
m. Highly mixed
d. Dense understory
e. No dense understory

Age Structure (list no. classes)

a. Even-aged
b. Uneven-aged

H.T. Slope

a. flat to 10%
b. 10-40%
c. 40-75%
d. 75+%

H.T. Dissection

a. highly
b. moderately
c. lightly

percent Interval Change

0 = Within natural range
10 = Exceeds by 10 percent
20 = Exceeds by 20 percent
etc...

Fire Severity

a. Non-lethal surf. fires
b. Std. repl. fires
c. Mixed pattern

Fire Size

0. less than 200 acres
a. 200 to 1000 acres
b. 1000 to 5000 acres
c. 5000 to 10,000 acres
d. 10,000 to 50,000 acres
e. 50,000+ acres

Fire Spread

a. Uniform
b. Patchy
c. Mixed Pattern

APPENDIX B

Area Surface Form List

S U R F A C E F O R M -- B R O A D S C A L E

LAINS
ittle
elief

Smooth plain

Irregular plain

Rough plain

LATEAU
Moderate
to great
elief

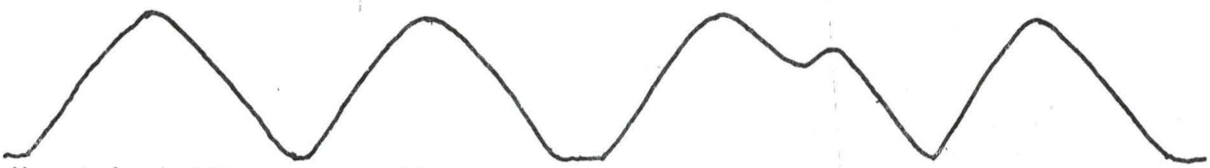
Plateau, tableland

HILLS
Moderate
elief

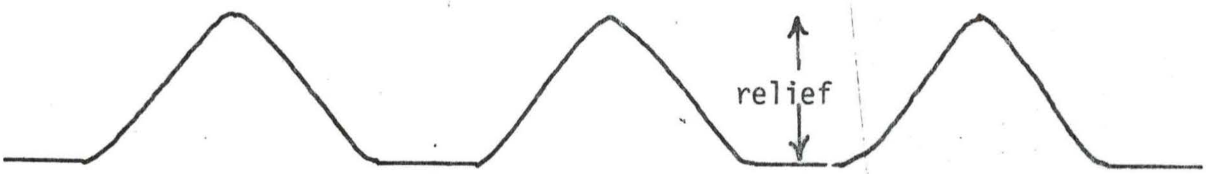
Hills with narrow valleys

Open hills, hills with broad valleys

MOUNTAINS
Great
elief



Mountains with narrow valleys



~~Open mountains,~~ Mountains with broad valleys Ca,b

LAINS
WITH
MOUNTAINS

Plains with mountains (Basin-and-Range topography)

John M. CROWLEY

Plateau-like mountains Cd

APPENDIX C

Land Dissection Template

Examples of H.I. Dissection: Moderately Highly

STANTON LAKE QUADRANGLE
MONTANA–FLATHEAD CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)

APPENDIX D

Literature Review Bibliography

(Note: Reports are indexed according to the order in which they were reviewed, rather than in alphabetical order, so that they can be cross-referenced to the fire regimes classification in Appendix F).

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APPENDIX E

Vegetation Classification according to estimated mean annual and mean fire season (July/August) precipitation in inches.

Classification		Mean Annual (S.Dev.)	Mean Fire Season
HABGROUP	**XERIC HABITATS**	**17.25 (6.69)**	**1.31 (0.73)**
MOISTURE	**DRY SITES**	**16.45 (6.53)**	**1.15 (0.62)**
STANDTYP	PIPO/INT PP	15.44 (4.76)	1.16 (0.59)
STANDTYP	PIPO/JUNIP	13.00 (0.00)	0.52 (0.00)
STANDTYP	PSME/INT PP	17.54 (7.79)	1.20 (0.65)
MOISTURE	**MODERATE SITES**	**19.69 (6.83)**	**1.78 (0.86)**
STANDTYP	PSME/INT PP	19.69 (6.83)	1.78 (0.86)
HABGROUP	**MODERATE HABITATS**	**29.70 (14.54)**	**2.35 (1.17)**
MOISTURE	**DRY SITES**	**18.85 (9.73)**	**1.82 (0.78)**
STANDTYP	ABCO/WF	48.00 (0.00)	1.92 (0.00)
STANDTYP	ABCO/INT PP	48.00 (0.00)	1.92 (0.00)
STANDTYP	ABGR/INT PP	15.42 (8.18)	0.71 (0.22)
STANDTYP	ABLA/INT DF	18.11 (3.78)	2.45 (0.30)
STANDTYP	PIFL/INT DF	15.23 (0.00)	1.98 (0.00)
STANDTYP	PSME/INT DF	16.48 (4.66)	1.92 (0.82)
STANDTYP	PSME/ASPEN	15.23 (0.00)	1.98 (0.00)
MOISTURE	**MODERATE SITES**	**30.79 (15.01)**	**2.47 (1.19)**
STANDTYP	ABAM/INT PP	35.00 (0.00)	0.35 (0.00)
STANDTYP	ABCO/INT DF	21.50 (0.00)	1.07 (0.00)
STANDTYP	ABCO/WF	67.00 (0.00)	2.68 (0.00)
STANDTYP	ABCO/INT PP	18.76 (9.03)	1.11 (0.51)
STANDTYP	ABGR/INT DF	27.08 (12.72)	1.13 (0.42)
STANDTYP	ABGR/INT PP	26.39 (10.76)	0.74 (0.41)
STANDTYP	ABLA/INT DF	20.00 (0.00)	2.60 (0.00)
STANDTYP	ABLA/ASPEN	20.00 (0.00)	2.60 (0.00)
STANDTYP	ABLA/LPP	31.86 (14.20)	3.08 (0.96)
STANDTYP	ABMA/LPP	60.67 (5.49)	2.43 (0.22)
STANDTYP	PICO/LPP	45.00 (19.37)	2.40 (0.16)
STANDTYP	PSME/INT DF	21.85 (10.12)	2.51 (1.29)
STANDTYP	PSME/LARCH	30.00 (0.00)	3.00 (0.00)
STANDTYP	PSME/ASPEN	20.00 (0.00)	2.60 (0.08)
STANDTYP	PSME/LPP	35.00 (0.00)	3.85 (0.00)
MOISTURE	**MOIST SITES**	**37.71 (9.84)**	**2.48 (1.31)**
STANDTYP	ABLA/LPP	36.88 (9.21)	2.54 (1.31)
STANDTYP	PSME/INT DF	56.00 (0.00)	1.12 (0.00)
HABGROUP	**MOIST HABITATS**	**60.05 (33.36)**	**3.09 (1.19)**
MOISTURE	**MODERATE SITES**	**32.18 (10.21)**	**3.35 (0.92)**
STANDTYP	ABGR/LARCH	18.00 (0.00)	2.34 (0.00)
STANDTYP	ABLA/ES-SAF	31.87 (9.11)	3.61 (0.87)
STANDTYP	PIAL/ES-SAF	30.00 (0.00)	3.30 (0.00)

STANDTYP	PICE/LARCH	23.06 (0.00)	2.51 (0.00)
STANDTYP	PICE/LPP	34.25 (11.06)	2.85 (1.19)

Classification		Mean Annual (S.Dev)	Mean Fire Season
HABGROUP:	**MOIST (cont.)**		
MOISTURE:	**MOD. SITES (cont.)**		
STANDTYP	TSME/LPP	57.50 (0.00)	2.30 (0.00)
MOISTURE	**MOIST SITES**	**64.70 (33.63)**	**3.03 (1.22)**
STANDTYP	ABAM/ES-SAF	90.50 (0.00)	2.41 (1.07)
STANDTYP	ABAM/FIR-WH	106.55 (14.51)	3.52 (0.83)
STANDTYP	ABAM/PAC DF	98.90 (9.16)	2.38 (0.40)
STANDTYP	ABGR/LARCH	37.50 (7.07)	2.03 (0.67)
STANDTYP	ABGR/GF	45.00 (0.00)	1.80 (1.03)
STANDTYP	ABLA/ES-SAF	45.30 (27.56)	3.40 (1.40)
STANDTYP	ABLA/WBP	29.33 (1.16)	2.57 (1.26)
STANDTYP	ABLA/LARCH	32.41 (4.81)	2.85 (0.94)
STANDTYP	ABLA/FIR-WH	80.00 (0.00)	1.60 (0.00)
STANDTYP	LALY/WBP	40.00 (0.00)	4.60 (0.23)
STANDTYP	PIAL/WBP	42.50 (2.89)	5.33 (0.61)
STANDTYP	PICE/LPP	40.00 (0.00)	4.40 (1.20)
STANDTYP	THPL/LARCH	41.42 (4.89)	1.86 (0.21)
STANDTYP	THPL/WWP	37.85 (3.68)	2.08 (0.20)
STANDTYP	THPL/WRC-WH	59.19 (29.89)	2.46 (0.74)
STANDTYP	THPL/WRC	41.00 (5.48)	1.64 (0.22)
STANDTYP	THPL/DF-WH	71.00 (0.00)	1.62 (1.57)
STANDTYP	TSHE/LARCH	30.00 (0.00)	3.50 (0.00)
STANDTYP	TSHE/WH	93.00 (0.00)	3.72 (0.00)
STANDTYP	TSHE/FIR-WH	93.00 (0.00)	3.72 (2.67)
STANDTYP	TSHE/WRC-WH	90.50 (0.00)	2.41 (0.00)
STANDTYP	TSHE/PAC DF	92.50 (0.00)	1.95 (0.00)
STANDTYP	TSHE/DF-WH	108.79 (19.39)	3.92 (1.33)
	Entire Population:	43.40 (30.72)	2.58 (1.28)

APPENDIX F

Fire Regimes Classification indexed according to Appendix D literature review reference numbers.

Classification		Reference Numbers
HABGROUP	XERIC HABITATS	
FIREREGM	NONLETHAL-NONUNIFORM	
STANDTYP	PIPO/INT PP	3, 6
STANDTYP	PSME/INT PP	1, 3, 4, 6, 26, 28, 35
FIREREGM	NONLETHAL-UNIFORM	
STANDTYP	PIPO/INT PP	1, 8, 18, 19, 20, 47
STANDTYP	PIPO/JUNIP	18
STANDTYP	PSME/INT PP	1, 7, 9, 33, 34, 38, 50
HABGROUP	MODERATE HABITATS	
FIREREGM	NONLETHAL-NONUNIFORM	
STANDTYP	ABCO/WF	27
STANDTYP	ABCO/INT PP	27, 35, 47
STANDTYP	ABGR/INT PP	28, 35
STANDTYP	ABLA/LPP	26
STANDTYP	ABMA/LPP	27
STANDTYP	PSME/INT DF	1, 3, 6
STANDTYP	PSME/LARCH	26
FIREREGM	NONLETHAL-UNIFORM	
STANDTYP	ABAM/INT PP	34
STANDTYP	ABCO/INT DF	33
STANDTYP	ABGR/INT DF	50
STANDTYP	ABGR/INT PP	34, 38
STANDTYP	ABLA/INT DF	12, 13
STANDTYP	PIFL/INT DF	30
STANDTYP	PSME/INT DF	8, 9, 20, 29, 30, 32, 37
STANDTYP	PSME/ASPEN	29
FIREREGM	MIXED-NONUNIFORM	
STANDTYP	ABGR/INT DF	28, 48
STANDTYP	ABGR/INT PP	48
STANDTYP	ABLA/INT DF	32
STANDTYP	ABLA/ASPEN	12
STANDTYP	ABLA/LPP	3, 4, 12, 13, 16, 22, 32, 39, 40, 52
STANDTYP	ABMA/LPP	40
STANDTYP	PICO/LPP	40
STANDTYP	PSME/INT DF	14, 17, 28
STANDTYP	PSME/ASPEN	12
STANDTYP	PSME/LPP	14
FIREREGM	LETHAL-NONUNIFORM	
STANDTYP	ABLA/LPP	11, 14, 15, 36, 50

STANDTYP	PICO/LPP	11
FIREREGM	LETHAL-UNIFORM	
STANDTYP	ABLA/LPP	2, 5, 15, 21, 22, 41, 49, 51
HABGROUP	MOIST HABITATS	
FIREREGM	NONLETHAL-NONUNIFORM	
STANDTYP	PICE/LARCH	4
FIREREGM	NONLETHAL-UNIFORM	
STANDTYP	ABLA/ES-SAF	29
FIREREGM	MIXED-NONUNIFORM	
STANDTYP	ABAM/FIR-WH	42, 45
STANDTYP	ABAM/PAC DF	44, 45
STANDTYP	ABGR/LARCH	3, 16, 26
STANDTYP	ABGR/GF	16
STANDTYP	ABLA/ES-SAF	13, 52
STANDTYP	ABLA/WBP	52
STANDTYP	ABLA/LARCH	26, 52
STANDTYP	LALY/WBP	22
STANDTYP	PIAL/WBP	3, 22
STANDTYP	PICE/LPP	4, 39
STANDTYP	THPL/LARCH	16
STANDTYP	THPL/WRC	16
STANDTYP	TSHE/PAC DF	44
STANDTYP	TSHE/DF-WH	42
STANDTYP	TSME/LPP	40
FIREREGM	LETHAL-NONUNIFORM	
STANDTYP	ABAM/ES-SAF	45
STANDTYP	ABAM/FIR-WH	23, 25, 43, 45
STANDTYP	ABAM/PAC DF	43
STANDTYP	ABGR/LARCH	10, 49, 50
STANDTYP	ABLA/ES-SAF	2, 12, 15, 36, 46
STANDTYP	ABLA/WBP	12
STANDTYP	ABLA/LARCH	2, 50
STANDTYP	LALY/WBP	15
STANDTYP	PIAL/ES-SAF	12
STANDTYP	PICE/LPP	14
STANDTYP	THPL/LARCH	10, 24, 49
STANDTYP	THPL/WWP	10, 24
STANDTYP	THPL/WRC-WH	10, 23, 24, 45
STANDTYP	THPL/WRC	16, 49
STANDTYP	TSHE/WH	23
STANDTYP	TSHE/FIR-WH	23
STANDTYP	TSHE/WRC-WH	45
STANDTYP	TSHE/DF-WH	25, 45
FIREREGM	LETHAL-UNIFORM	
STANDTYP	ABLA/ES-SAF	10, 15, 21, 22, 41
STANDTYP	ABLA/LARCH	5, 41, 51
STANDTYP	ABLA/FIR-WH	21
STANDTYP	THPL/DF-WH	21
STANDTYP	TSHE/LARCH	41
STANDTYP	TSHE/DF-WH	21, 31

APPENDIX G

Suggested fire regimes key format for fire regimes classification in table 5.

XERIC HABITATS DRY SITES FIRE REGIME

Habitats
PIPO/JUNIP
PIPO/INT PP
PSME/INT PP
MFI 14.4
Samples 52

Moisture : Dry	
Mean Fire Int :	13.2
Annual Precip :	16.4
Seasonal Precip:	1.1
Samples :	39

Severity : Non-Lethal Spread : Non-Uniform	
Mean Fire Int :	12.3
Sup Min Factor :	2.1
Sup Max Factor :	7.5
Samples :	12

Severity : Non-Lethal Spread : Uniform	
Mean Fire Int :	13.6
Sup Min Factor :	1.3
Sup Max Factor :	16.3
Samples :	27

Severity : Mixed Spread : Non-Uniform	
Mean Fire Int :	
Sup Min Factor :	
Sup Max Factor :	
Samples :	0

Severity : Lethal Spread : Non-Uniform	
Mean Fire Int :	
Sup Min Factor :	
Sup Max Factor :	
Samples :	0

Severity : Lethal Spread : Uniform	
Mean Fire Int :	
Sup Min Factor :	
Sup Max Factor :	
Samples :	0

XERIC HABITATS   MODERATE SITES   FIRE REGIME

Habitats	
PIPO/JUNIP	
PIPO/INT DF	
PSME/INT DF	
MFI	14.4
Samples	52

Moisture : Moderate	
Mean Fire Int :	18.1
Annual Precip :	19.7
Seasonal Precip:	1.8
Samples :	13

Severity : Non-Lethal Spread : Non-Uniform	
Mean Fire Int :	17.0
Sup Min Factor :	2.3
Sup Max Factor :	8.5
Samples :	9

Severity : Non-Lethal Spread : Uniform	
Mean Fire Int :	20.5
Sup Min Factor :	1.4
Sup Max Factor :	8.8
Samples :	4

Severity : Mixed Spread : Non-Uniform	
Mean Fire Int :	
Sup Min Factor :	
Sup Max Factor :	
Samples :	0

Severity : Lethal Spread : Non-Uniform	
Mean Fire Int :	
Sup Min Factor :	
Sup Max Factor :	
Samples :	0

Severity : Lethal Spread : Uniform	
Mean Fire Int :	
Sup Min Factor :	
Sup Max Factor :	
Samples :	0

MODERATE HABITATS DRY SITES FIRE REGIME

Habitats
ABAM/INT PP
ABCO/INT DF
/INT PP
/WF
ABGR/INT DF
/INT PP
ABLA/ASPEN
/INT DF
/LPP
ABMA/LPP
PICO/LPP
PIFL/INT DF
PSME/ASPEN
/INT DF
/LARCH
/LPP
MFI 89.5
Samples 139

Moisture : Dry	
Mean Fire Int :	28.8
Annual Precip :	18.8
Seasonal Precip:	1.8
Samples :	26

Severity : Non-Lethal Spread : Non-Uniform	
Mean Fire Int :	16.5
Sup Min Factor :	1.0
Sup Max Factor :	10.3
Samples :	4

Severity : Non-Lethal Spread : Uniform	
Mean Fire Int :	28.3
Sup Min Factor :	1.0
Sup Max Factor :	10.3
Samples :	21

Severity : Mixed Spread : Non-Uniform	
Mean Fire Int :	90.0
Sup Min Factor :	1.5
Sup Max Factor :	11.7
Samples :	1

Severity : Lethal Spread : Non-Uniform	
Mean Fire Int :	
Sup Min Factor :	
Sup Max Factor :	
Samples :	0

Severity : Lethal Spread : Uniform	
Mean Fire Int :	
Sup Min Factor :	
Sup Max Factor :	
Samples :	0

MODERATE HABITATS — MODERATE SITES — FIRE REGIME

MODERATE HABITATS

Habitats
ABAM/INT PP
ABCO/INT DF
/INT PP
/WF
ABGR/INT DF
/INT PP
ABLA/ASPEN
/INT DF
/LPP
ABMA/LPP
PICO/LPP
PIFL/INT DF
PSME/ASPEN
/INT DF
/LARCH
/LPP

MFI	89.5
Samples	139

MODERATE SITES

Moisture	Moderate
Mean Fire Int	94.7
Annual Precip	30.8
Seasonal Precip	2.5
Samples	90

FIRE REGIME

Severity	Non-Lethal
Spread	Non-Uniform
Mean Fire Int	18.1
Sup Min Factor	2.3
Sup Max Factor	8.5
Samples	14

Severity	Non-Lethal
Spread	Uniform
Mean Fire Int	17.4
Sup Min Factor	2.3
Sup Max Factor	8.5
Samples	14

Severity	Mixed
Spread	Non-Uniform
Mean Fire Int	73.0
Sup Min Factor	1.4
Sup Max Factor	7.5
Samples	39

Severity	Lethal
Spread	Non-Uniform
Mean Fire Int	248.6
Sup Min Factor	1.0
Sup Max Factor	2.4
Samples	14

Severity	Lethal
Spread	Uniform
Mean Fire Int	188.9
Sup Min Factor	1.0
Sup Max Factor	1.6
Samples	9

MODERATE HABITATS MOIST SITES FIRE REGIME

Habitats
ABAM/INT PP
ABCO/INT DF
/INT PP
/WF
ABGR/INT DF
/INT PP
ABLA/ASPEN
/INT DF
/LPP
ABMA/LPP
PICO/LPP
PIFL/INT DF
PSME/ASPEN
/INT DF
/LARCH
/LPP
MFI 89.5
Samples 139

Moisture : Moist	
Mean Fire Int	137.4
Annual Precip	37.7
Seasonal Precip	2.5
Samples	23

Severity	Spread	Mean Fire Int	Sup Min Factor	Sup Max Factor	Samples
Non-Lethal	Non-Uniform				0
Non-Lethal	Uniform				0
Mixed	Non-Uniform	71.5	1.0	4.4	11
Lethal	Non-Uniform	275.0	1.0	1.0	3
Lethal	Uniform	172.0	1.0	1.6	9

MOIST HABITATS MODERATE SITES FIRE REGIME

Habitats
ABAM/ES-SAF
/FIR-WH
/PAC DF
ABGR/GF
/LARCH
ABLA/ES-SAF
/FIR-WH
/LARCH
/WBP
LALY/WBP
PIAL/ES-SAF
/WBP
PICE/LARCH
/LPP
PSME/DF-WH
/FIR-WH
/PAC DF
THPL/DF-WH
/LARCH
/WRC
/WRC-WH
/WWP
TSME/DF-WH
/FIR-WH
/LARCH
/LPP
/PAC DF
/WH
MFI 226.4
Samples 196

Moisture : Moderate	
Mean Fire Int :	185.9
Annual Precip :	32.2
Seasonal Precip:	3.3
Samples :	28

Severity : Non-Lethal Spread : Non-Uniform	
Mean Fire Int :	27.0
Sup Min Factor :	1.0
Sup Max Factor :	2.5
Samples :	1

Severity : Non-Lethal Spread : Uniform	
Mean Fire Int :	38.0
Sup Min Factor :	1.0
Sup Max Factor :	2.5
Samples :	2

Severity : Mixed Spread : Non-Uniform	
Mean Fire Int :	74.6
Sup Min Factor :	1.0
Sup Max Factor :	3.4
Samples :	7

Severity : Lethal Spread : Non-Uniform	
Mean Fire Int :	298.3
Sup Min Factor :	1.0
Sup Max Factor :	1.0
Samples :	12

Severity : Lethal Spread : Uniform	
Mean Fire Int :	166.7
Sup Min Factor :	1.1
Sup Max Factor :	3.7
Samples :	6

MOIST HABITATS

Habitats
ABAM/ES-SAF
/FIR-WH
/PAC DF
ABGR/GF
/LARCH
ABLA/ES-SAF
/FIR-WH
/LARCH
/WBP
LALY/WBP
PIAL/ES-SAF
/WBP
PICE/LARCH
/LPP
PSME/DF-WH
/FIR-WH
/PAC DF
THPL/DF-WH
/LARCH
/WRC
/WRC-WH
/WWP
TSHE/DF-WH
/FIR-WH
/LARCH
/LPP
/PAC DF
/WH
MFI 226.4
Samples 196

MOIST SITES

Moisture : Moist	
Mean Fire Int :	233.2
Annual Precip :	64.7
Seasonal Precip:	3.0
Samples :	168

FIRE REGIME

Severity : Non-Lethal Spread : Non-Uniform	
Mean Fire Int :	
Sup Min Factor :	
Sup Max Factor :	
Samples :	0

Severity : Non-Lethal Spread : Uniform	
Mean Fire Int :	
Sup Min Factor :	
Sup Max Factor :	
Samples :	0

Severity : Mixed Spread : Non-Uniform	
Mean Fire Int :	135.0
Sup Min Factor :	1.0
Sup Max Factor :	3.0
Samples :	44

Severity : Lethal Spread : Non-Uniform	
Mean Fire Int :	266.2
Sup Min Factor :	1.0
Sup Max Factor :	1.1
Samples :	88

Severity : Lethal Spread : Uniform	
Mean Fire Int :	272.7
Sup Min Factor :	1.0
Sup Max Factor :	1.0
Samples :	36